WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

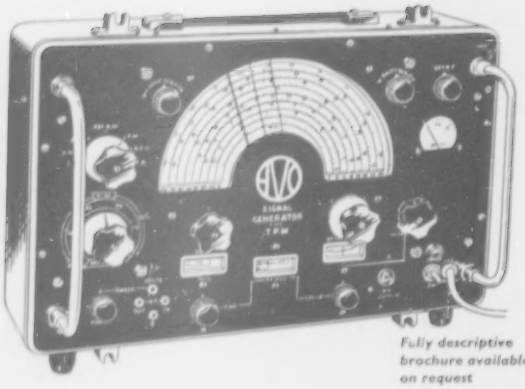
OCTOBER 1956

Vol. 33 No. 10 · THREE SHILLINGS AND SIXPENCE

WIDE BAND
SIGNAL GENERATOR
Type T.F.M.

Regd Trade Mark

The design of this new Wide Band Signal Generator, **operating throughout on fundamentals**, is the outcome of considerable research and development work to meet the stringent requirements imposed by new frequency modulation and commercial television stations.



Fully descriptive brochure available on request

The frequency bands have been chosen in such a manner as to ensure maximum convenience when servicing and aligning T.V. and F.M. receivers.

Provision has been made for spot R.F. frequency calibration.

Facilities are provided to ensure adequate discrimination throughout the very wide frequency band covered by the instrument.

Sine and square wave audio frequency modulation provided.

The instrument is fitted with an R.F. carrier level meter.

A double-ratio slow-motion mechanism, together with interpolation dial, enables the instrument to be set with a high degree of accuracy. On the F.M. range an internal phasing control enables the modulating signal to be applied to the X-plates of an oscillograph to produce a picture of a discriminator response curve.

AM COVERAGE

5-220 Mc/s in 8 ranges. CW or 400 c/s sine/square wave modulation. Accuracy ± 1%. Provision for spot frequency calibration.

FM COVERAGE

65-120 Mc/s. Accuracy ± 1%. Maximum deviation ± 150 Kc/s.

OUTPUT

Minimum (about 2μV) to 100 mV continuously variable with decade multiplier. Force output 250 mV.

OUTPUT IMPEDANCE

80Ω, 200Ω, balanced 80Ω and 300Ω, isolated unbalanced 80Ω.

OPERATING VOLTAGES

100-120V, 200-260V, 50-60 c/s A.C. mains.

LIST PRICE £89

DIMENSIONS

15¼ x 10¼ x 10 in. approx. with lid closed.

WEIGHT: 16 lb. approx.

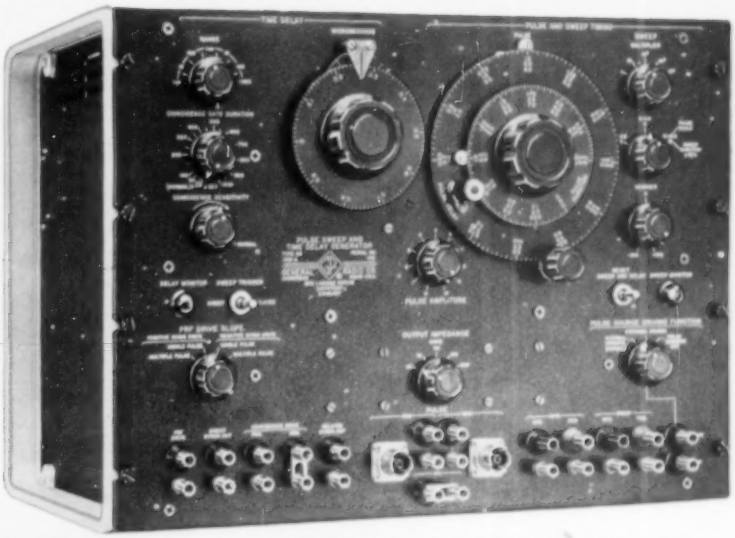
Sole Proprietors and Manufacturers

The AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.

AVOCET HOUSE · 92-96 VAUXHALL BRIDGE ROAD LONDON · S.W.1

Telephone: VICtoria 3404 (9 lines)

An extremely versatile generator for time-domain measurements



'GENERAL RADIO' TYPE 1391-A PULSE, SWEEP AND TIME-DELAY GENERATOR

The new Type 1391-A Pulse, Sweep and Time-Delay Generator performs, individually and in combination, all the functions described by its title and performs them all well; its excellent performance results from a minimum number of compromises in design. Its wide ranges and complete flexibility of circuit interconnection make it a highly satisfactory pulse generator for laboratories engaged in time-domain measurements and waveform synthesis.

The transition times of the output pulses are compatible with most present-day oscilloscopes. The internal sweep circuit makes it possible to deflect an inexpensive oscilloscope by direct connection to the deflecting plates, to monitor the output pulse.

Among its many applications are measurement and testing in the fields of:

Echo ranging	Computers
Radio navigation	Telemetering
Television	Physiological research

DESCRIPTION The Pulse, Sweep and Time-Delay Generator consists of the following major circuit groups: (1) input synchronizing circuits, (2) delay and coincidence circuits, (3) sweep circuits, and (4) pulse-timing and pulse-forming circuits.

3 INSTRUMENTS IN 1

PULSE GENERATOR SWEEP GENERATOR TIME-DELAY GENERATOR

This is truly a *complete* Time-Domain Measuring Instrument, giving the best performance obtainable with ultra-modern techniques plus the finest obtainable materials and components, backed by over forty years manufacturing experience. A very well thought-out design, developed over several years, provides the pulse specialist with the equipment he has long been seeking.

SUPERIOR PULSE CHARACTERISTICS:
Excellent Rise and Decay Times: 0·025 ± 0·01 μsec.
No Duty-Ratio or Frequency Restrictions on the Pulse.

HIGH BASIC TIMING ACCURACY:
Timing Scales are Linearly Calibrated, and accurate to 1%.

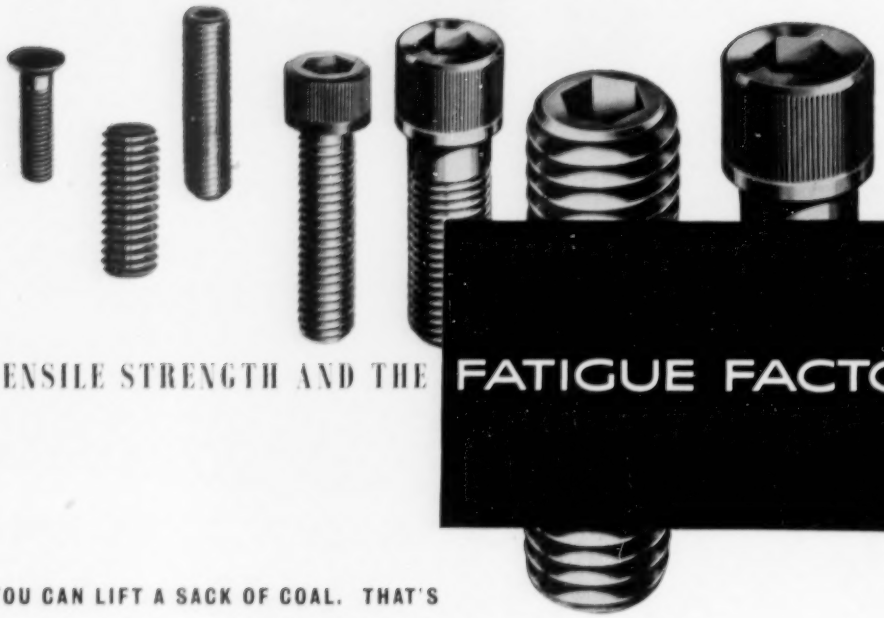
WIDE RANGES OF:
PULSE DURATION: 0·05 μsec—1·1 sec.
PULSE REPETITION RATE: 0-250 kc.
TIME DELAY: 1 μsec—1·1 sec.
DELAY REPETITION RATE: 0-400 kc.
OUTPUT IMPEDANCE: 0-600 ohms.

This is a large instrument, and it is supplied complete with its necessary power supply (not illustrated), arranged at choice for bench or rack operation. The Generator proper has thirty-six vacuum tubes. Considering its flexibility and completeness the price is reasonable—£1,047 net delivered (U.K. only). For complete data see the 13-page article in "GENERAL RADIO EXPERIMENTER" for May 1956 (Vol. 30, No. 12), or request the latest "G.R." Catalogue 'O'. Send your written application to our nearest address, please.

Claude Lyons Ltd.

76 OLDHALL STREET · LIVERPOOL ● VALLEY WORKS · HODDESDON · HERTS

Telephone: Central 4641/2 Telephone: Hoddesdon 3007 (4 lines)

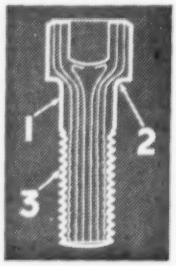


TENSILE STRENGTH AND THE FATIGUE FACTOR

MAYBE YOU CAN LIFT A SACK OF COAL. THAT'S STRENGTH, BUT WHEN YOU'VE BEEN DOING IT ALL DAY, THAT'S FATIGUE.

It has always been an easy matter to show a high Rockwell reading of hardness by merely heat treating any one of many varied steels. These steels may show up splendidly in a tensile test, but are completely worthless on today's higher speed machines and heavier stress forming service conditions. Why are they worthless? They have no fatigue life. Fatigue is a factor which has only received full consideration in recent years. It simply means that metal gets tired and gives way under continual stress, as when you bend a piece of wire back and forth until it breaks.

Unbrako technicians constantly strive to achieve the perfect balance between tensile strength and fatigue resistance. That is why Unbrako use only best quality Alloy Steel to their own exacting specifications, and make screws to the highest possible standards of unvarying precision. At the trouble spot under the head (1) *Unbrako have a fatigue-resisting fillet. At the thread root* (3), *fatigue resistance is greatly increased by the continuous closely-knit grain flow and rolled thread* (2) *and superior notch-free surface finish. No doubt, Unbrako make the world's finest screws and you can specify them with confidence. May we send you fuller details?*



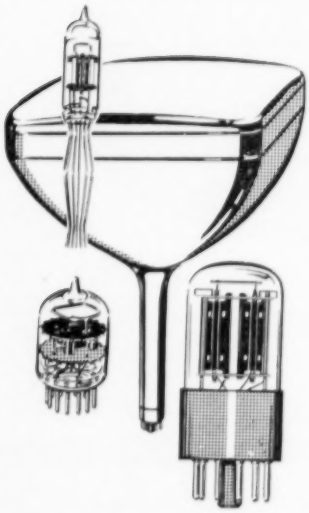
UNBRAKO

UNBRAKO SCREWS COST LESS THAN TROUBLE

THE UNBRAKO SOCKET SCREW COMPANY LIMITED · COVENTRY

If you manufacture ELECTRON TUBES

LUMA supplies material



Manufacturing all types of incandescent, mercury vapour, neon and flourescent lamps, fluorescent fittings and accessories.

90 % of Luma's production of tungsten and molybdenum wire is exported. Luma's wire and coiled filaments for radio valves and other uses are sold in more than 40 countries.

Lumalampan AB runs its own tungsten and molybdenum works in order to have these important elements under its own control. Modern laboratories maintain an efficient production control and ensure progressive technical development.

Consult LUMA about tungsten and molybdenum wire and coiled filaments. Wire is supplied in all dimensions and finishes, e. g. black, cleaned or plated, semi-finished rods or finished electrodes.

Plated wire supplied in the following forms, among others: gold-plated tungsten wire, gold-, silver- or nickel-plated molybdenum wire.

Outstanding properties of LUMA's plated wire:

impermeable coating with good bond to base metal
bright surface
uniform mechanical properties,

which efficiently prevent oxidation and grid emission.

The Luma Factory, the largest of its kind in Scandinavia has high capacity and short delivery times.

Our tungsten wire catalogue, in English, German or French, will be sent on request.

LUMALAMPAN AB

Address: Stockholm 20 Sweden
Cables: LUMALAMPAN Stockholm

MUTUAL & SELF INDUCTANCE BRIDGE

Designed for the accurate measurement of either mutual or self inductance and resistance in the range 0·001 μH to 30mH and 100 $\mu\Omega$ to 3000 Ω respectively.

All measurements are made in the form of a four-terminal network and inductance and resistance of leads and clips are not included in the measurement.

Accuracy within $\pm$ 1% frequency 1592c/s (ω = 10 000)

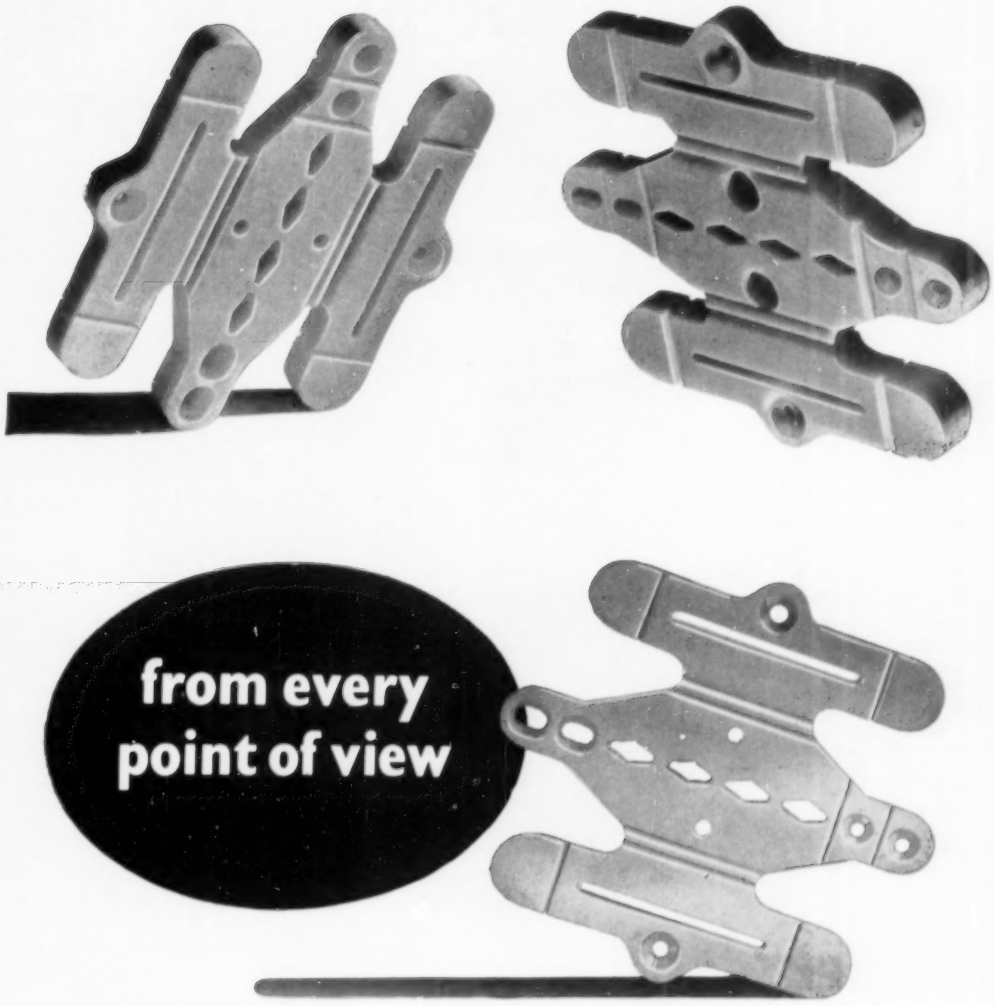
Full technical information on this and other 'Cintel' Bridges is available on request.

CINEMA TELEVISION LTD

A COMPANY WITHIN THE RANK ORGANISATION LIMITED

WORSLEY BRIDGE ROAD · LONDON · S.E.26
HITHER GREEN 4600

SALES AND SERVICING AGENTS:
Hawnt & Co. Ltd., 59 Moor St. Birmingham, 4
Atkins, Robertson & Whiteford Ltd., 100 Torrisdale Street, Glasgow, S.2
F. C. Robinson & Partners Ltd., 122 Seymour Grove, Old Trafford, Manchester 16



'Frequentite' is the most suitable insulating material for all high frequency applications. Seventeen years ago we introduced the first British-made low-loss ceramic, and consultation with us before finalising the design of new components is a wise precaution.

STEATITE & PORCELAIN PRODUCTS LTD.

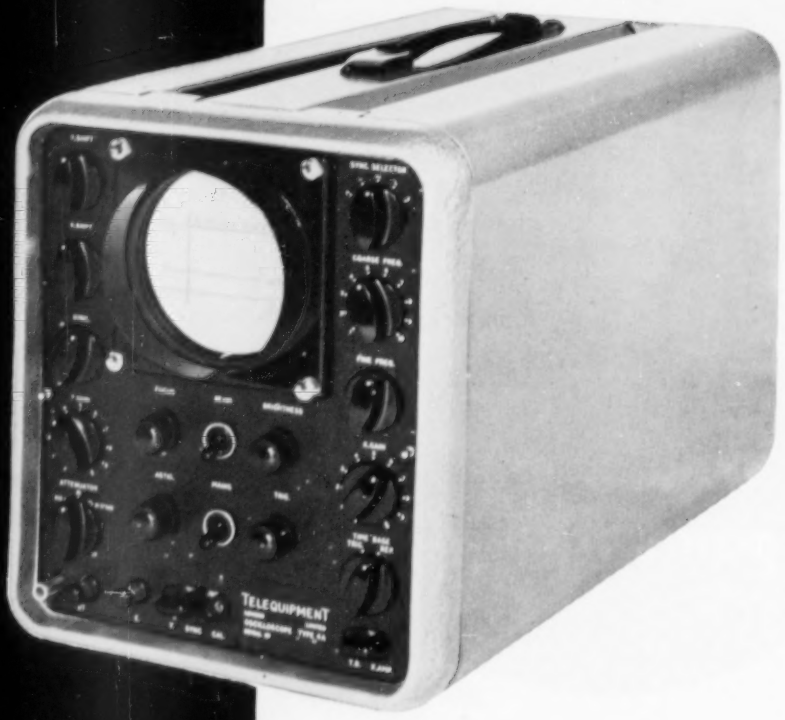
Head Office: Stourport-on-Severn, Worcestershire. Telephone: Stourport 111. Telegrams: Steatain, Stourport

S.P.66

the new

"620" OSCILLOSCOPE

by TELEQUIPMENT



- **CONSTANT BANDWIDTH AMPLIFIER**
  –3dB at 6·5 Mc/s
  Max. sensitivity 50mV/cm
- **WIDE RANGE TIME BASE**
  10 c/s to 300 Kc/s
- **X EXPANSION**
  up to at least 5 diameters
- **VOLTAGE CALIBRATOR**
  1 V p.p. square wave ± 2%

A new general purpose portable oscilloscope designed primarily for TV and pulse investigation. Developed originally to a G.P.O. specification as a TV line monitor, the "620" offers an extremely high standard of performance at a reasonable price. The 4" flat faced P.D.A. tube operating at 2·8 kv gives an extremely fine bright trace enabling full use to be made of the wide band amplifier and wide range time base.

A built-in Voltage Calibrator allows accurate measurement of the input signal and an internal sync. separator facilitates locking to line or frame pulses of a TV waveform. The whole instrument is contained in an attractive hammer finished case and is built to withstand the rigours of portable operation. Please write or telephone for full details.

TELEQUIPMENT LTD

313 Chase Road, Southgate, London, N.14 · PALmers Green 7111

TWO NEW

G.E.C. Precision Instrument Tubes

4GP1

with a green screen having an afterglow of 100 milliseconds.

4GP11

with a photographic blue screen having an afterglow of 1 millisecond.

9cm close tolerance, high quality instrument cathode ray tubes with electrostatic focus and deflection. These tubes have the following attractive features:—

1. Plate glass screen.
2. One stage of post deflection acceleration.
3. Low interelectrode capacitances.
4. Overcapped pressed glass wafer seal.
5. Orthogonality of deflection axes $\pm$ 1°.
6. Spot centring. The undeflected spot will fall within a radius of 5 mms concentric with the tube face.
7. Deflection linearity. The plate sensitivity for a deflection of less than 75% of the useful scan will not differ from the plate sensitivity for a deflection of 25% of the useful scan by more than 2%.

List Price £10.

G.E.C. Valves

RATINGS

V_h	6.3V	
I_h	0.5A	
V_{a4}	8kV max.	
V_{a3}	4kV max.	
S_x	$\frac{620}{V_{a3}}$ mm/V	When $V_{a4}=2V_{a3}$
S_y	$\frac{400}{V_{a3}}$ mm/V	

TYPICAL OPERATION

V_{a4}	4.0kV
V_{a3}	2.0kV
V_{a2} (focus)	330 approx. V.
V_{a1}	2.0kV
V_g	(for cut-off)—67V
S_x	0.31 mm/V
S_y	0.2 mm/V

Line width 0.3 mms.

Additional technical information on these two new tubes may be obtained from the G.E.C. Valve and Electronics Dept.

THE GENERAL ELECTRIC CO. LTD. MAGNET HOUSE, KINGSWAY, LONDON, W.C.2.

MILLIVOLTMETER *Type 784*

(Wideband Amplifier and Oscilloscope Pre-Amplifier)

THIS instrument consists essentially of a high-impedance probe unit followed by a stable wide-band amplifier and diode voltmeter. Measurements may be made from 1 millivolt to 1 volt in the frequency range 30 c/s to 10 Mc/s. The provision of a low impedance output enables the instrument to be used as a general purpose amplifier in the frequency range 30 c/s to 15 Mc/s, or as an extremely sensitive pre-amplifier for the Airmec Oscilloscope Type 723.

- **Frequency range from 30 c/s to 10 Mc/s.**
- **Voltage ranges 0-10, 0-100, 0-1000 millivolts.**
- **Excellent stability.**
- **Can be used as an amplifier up to 15 Mc/s.**
- **Immediate delivery.**

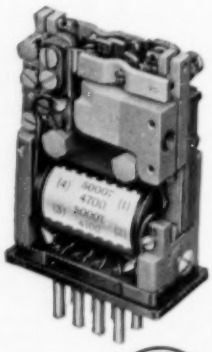
Full details of this or any other Airmec instrument will be forwarded gladly upon request.

AIRMEC LIMITED — HIGH WYCOMBE — BUCKINGHAMSHIRE — ENGLAND

Telephone: High Wycombe 2060 — *Cables:* Airmec, High Wycombe

TYPE 51A

CARPENTER POLARIZED RELAY

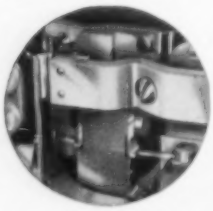


For circuits employing a polarized relay where a high order of relay stability is required, e.g., in aircraft control systems, we are now able to offer the *Type* 51A *Carpenter polarized relay.*

This new "each-side-stable" relay, designed principally for d.c. operation, is a development of the Type 5A relay well-known for its *high sensitivity, fast operation* and relative *freedom from contact bounce.* It has all the good qualities of the earlier model but its performance is markedly improved due to the fitting of a new form of armature suspension, (*see illustration below*) and provision for adjusting the flux of the polarizing magnets.

With an operate sensitivity of 2.5 ampere turns (approximately 60 micro-watts) the 51A relay will hold its adjustment between close limits over a fairly wide temperature range.

This relay is, therefore, offered and recommended as a direct replacement for all existing Type 5A relays used in d.c. applications where a higher order of stability and reliability is required.



To learn more about this relay send for Leaflet F.3526.

DIMENSIONS (*excluding connecting pins or tags*). **Height: 2¼ in. Width: 1½ in. Depth: ¾ in.**

Manufactured by the sole licensees

TELEPHONE MANUFACTURING COMPANY LTD

Hollingsworth Works · Dulwich · London · S.E.21 · Telephone: GIPsy Hill 2211

Photographs of 'Eclipse' magnets are reproduced by courtesy of the manufacturers James Neill & Company (Sheffield) Limited.

The remarkable efficiency of these 'Eclipse' magnets is due to their composite construction, using 'Araldite' to bond the component parts. The manufacturers of these magnets state that they use 'Araldite' because it enables them to produce shapes and sizes otherwise impracticable, to ensure that the magnets cannot be taken apart and to avoid bolted assemblies. 'Araldite' provides a bond which is truly permanent, and its strength is proved by the fact that facing and boring operations and also grinding are carried out after bonding.

'Araldite' epoxy resins have a remarkable range of characteristics and uses.

They are used

- ★ **for bonding metals, porcelain, glass etc.**
- ★ **for casting high grade solid insulation.**
- ★ **for impregnating, potting or sealing electrical windings and components.**
- ★ **for producing glass fibre laminates.**
- ★ **for producing patterns, models, jigs and tools.**
- ★ **as fillers for sheet metal work.**
- ★ **as protective coatings for metal, wood and ceramic surfaces.**

'Araldite' epoxy resins

'Araldite' is a registered trade name

Aero Research Limited *A Ciba Company · Duxford · Cambridge · Telephone: Sawston 2121*

AP. 264-190

Now Available!

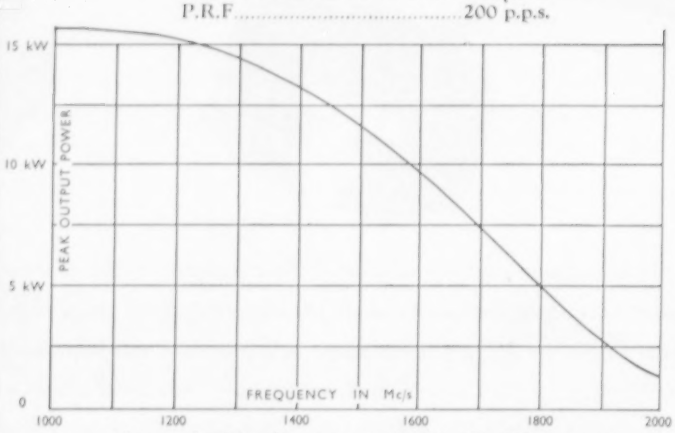
FERRANTI CERAMIC VALVES

TRIODE TYPE UL10
Less than 2½" x 1" max. dia.

TRIODE TYPE UL10

RF Output Power under PULSE Conditions

Pulse Va ..... 4 kV
Pulse Duration ..... 2½ μsec.
P.R.F ..... 200 p.p.s.



Also suitable for use as C.W. Oscillator or Amplifier giving outputs up to 15 Watts at frequencies up to 1000 Mc/s.

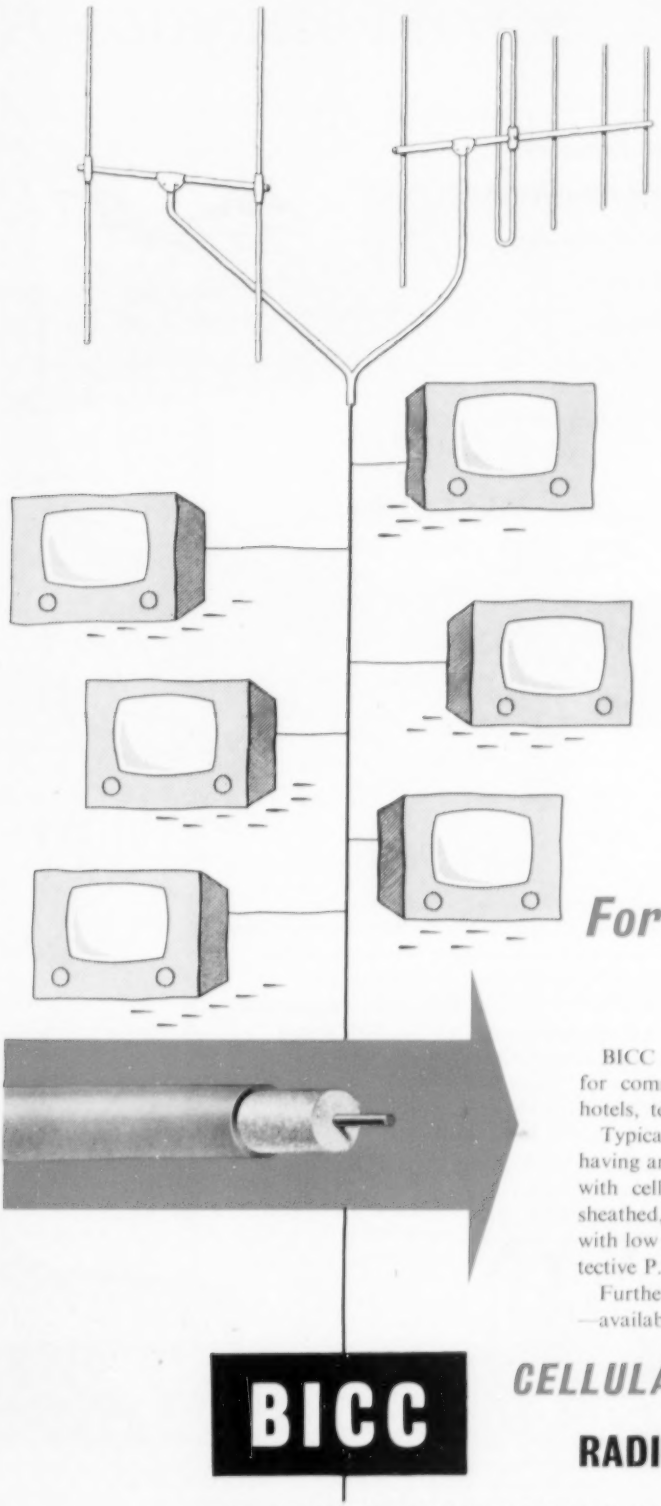
All Ferranti Ceramic Valves have the following outstanding advantages

- LONG LIFE
- REDUCED DIMENSIONS
- HIGH PEAK EMISSION
- HIGH MECHANICAL STRENGTH
- HIGH PERMISSIBLE TEMPERATURE OF OPERATION

FERRANTI

FERRANTI LTD · CREWE TOLL · FERRY ROAD · EDINBURGH 5
LONDON OFFICE: KERN HOUSE · 36 KINGSWAY · W.C.2.

ES/T28



For Communal T/V Aerial Systems

BICC make all types of radio frequency cables for communal television aerial systems in flats, hotels, television showrooms, hostels and hospitals.

Typical of the most popular range is a cable having an inner conductor of copper wire, insulated with cellular polythene dielectric and lead alloy sheathed, thus giving excellent screening properties with low attenuation. For certain situations a protective P.V.C. oversheath may be provided.

Further details are given in Publication TD T 23 —available on request.

BICC

CELLULAR POLYTHENE

RADIO FREQUENCY CABLES

BRITISH INSULATED CALLENDER'S CABLES LIMITED, 21 BLOOMSBURY STREET, LONDON, W.C.1

Consistency of Performance

Toroidally Wound Power Potentiometers

Carbon Composition and Wirewound Potentiometers

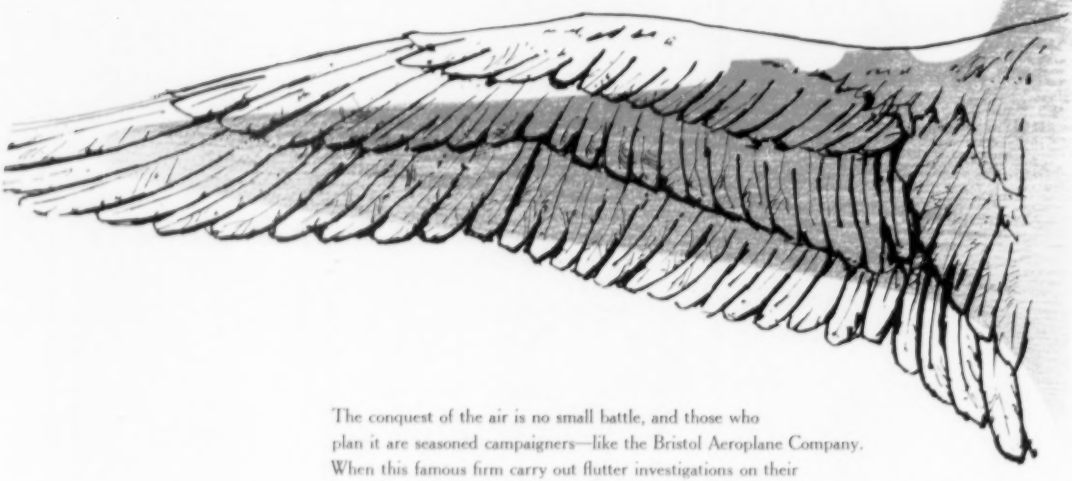
Panclimatic High Stability Carbon Resistors

Insulated High Stability Carbon Resistors

High Voltage Composition Resistors

'Welmet' Metal Film Resistors

'Vitricon' Miniature Vitreous Enamelled Capacitors



The conquest of the air is no small battle, and those who plan it are seasoned campaigners—like the Bristol Aeroplane Company. When this famous firm carry out flutter investigations on their aircraft they use an analogue computer of great speed and accuracy. It is, in fact, a test within a test for the exactitude of its components—not the least of which are 5,000 Welwyn high stability carbon resistors and vitreous enamelled wirewound resistors. Chosen for their proven features, these Welwyn resistors have proved their absolute reliability in the hardest possible trial.

MANUFACTURERS OF
WELWYN
ELECTRICAL
COMPONENTS

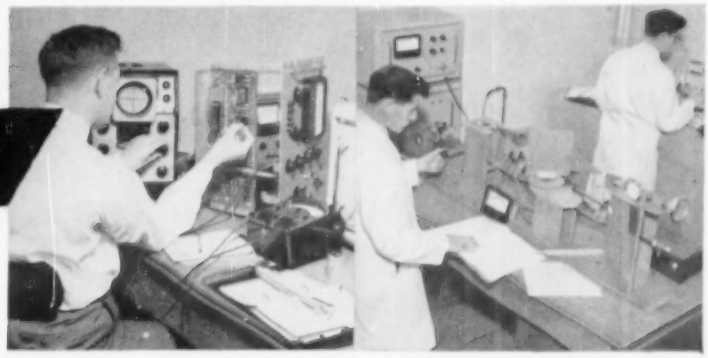
WELWYN ELECTRICAL LABORATORIES LIMITED · BEDLINGTON · NORTHUMBERLAND

Canada: Welwyn Canada Ltd., 1255 Brydges Street, London, Ontario
U.S.A.: Welwyn International Inc., 3355 Edgecliffe Terrace, Cleveland 11, Ohio
On Admiralty, Ministry of Supply (A.I.D. Approved) and Post Office Lists

A complete service

to Research and Industry

Measurements



Instrument Design

Design and development of instruments, microwave components and equipment.

Manufacturing capacity for prototypes and batch quantities. Full A.I.D. approval.

Specifications accepted at any stage and translated into your final requirements.

Investigations of dielectric materials over a wide range of temperature and frequency.

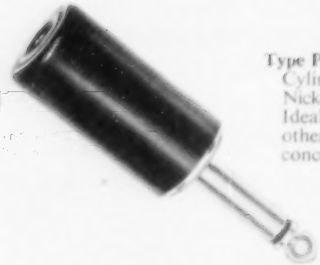
Specialist experience available to undertake component measurements.

Microcell Electronics

A DIVISION OF MICROCELL LIMITED · IMPERIAL BUILDINGS, 56 KINGSWAY, W.C.2

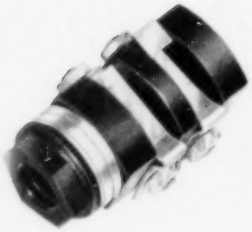
TELEPHONE: BISHOPSGATE 6801

MIC 7899



Type P 50 Plug
Cylindrical bakelite case. Nickel plated metal parts. Ideal for amplifiers and other applications where concentric cable is used.

Midget Jack. P 73
Moulded bakelite. Suitable for switching-in high frequency circuits. Capacity between springs eliminated. Silver contacts, one hole fixing, perfect contact.



reliability PLUS delivery

Igranic Plugs and Jacks have always had a justifiable reputation for dependability. For radio, television, office appliances and the hundred and one industrial plug-in applications demand has hitherto outstripped supply. NOW, with increased production facilities, Igranic Plugs and Jacks are available again for manufacturers to whom only the best is good enough.

Type P 40 Plug
Moulded bakelite. Nickel plated metal parts. Especially suitable for extension speakers, headphones and similar application.

IGRANIC ELECTRIC COMPANY LIMITED *HEAD OFFICE & WORKS BEDFORD*

London and Export Office VICTORIA STATION HOUSE 191 VICTORIA STREET LONDON SW1 GRAMS IGRANIC LONDON
Branch Offices BIRMINGHAM BRISTOL CARDIFF EAST ANGLIA GLASGOW LEEDS MANCHESTER NEWCASTLE SHEFFIELD
A METAL INDUSTRIES GROUP COMPANY

IG/52/P2842

FORTIPHONE

SUBMINIATURE A.F. TRANSFORMERS

PROTOTYPE SERVICE FOR EQUIPMENT DESIGNERS

Prototypes of special windings can be supplied quickly at a nominal development charge. It is recommended that designers first establish the approximate circuit requirements with a multi-ratio transformer (such as types MM-1A or B), and then take the nearest of the 36 single-ratio standard windings (samples are available from stock).

Having established the limiting values for size, inductance, d.c. saturation or resistance, as the case may be, a discussion with our engineers is helpful in arriving at an optimum design, and the most suitable finish.

Details of this prototype service, with design notes on transformers and transductors, and data on our standard range, will be sent on request.

FORTIPHONE, LTD.— COMPONENT DIVISION
92, Middlesex Street, London, E.1.

Comprehensive, up-to-date... operating characteristics of over 2,800 valves & C.R. tubes

5th EDITION NOW READY

RADIO VALVE DATA

Compiled by "Wireless World"

Gives in tabular form the characteristics of approximately 2,500 types of British and American valves and of 37 transistors for radio, telecommunications and electronic circuits, together with particulars of over 300 cathode ray tubes.

The main tables give the electrical characteristics of each valve, and include a key to the valve base connections of which there are 19 pages of diagrams. The main tables further classify the valves into current, replacement or obsolete types as recommended by the makers.

11" × 8½" 126 pp.

4s. 6d. net

BY POST 5s. 1d.

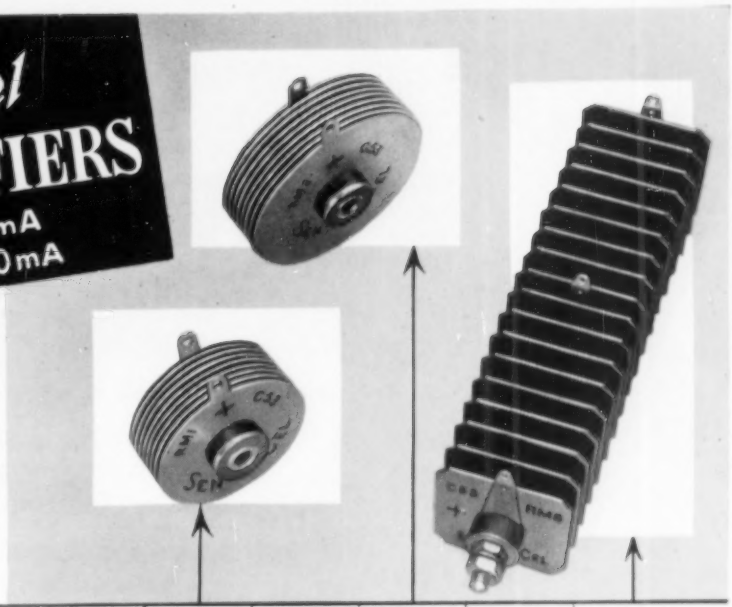
from all booksellers

Published for "Wireless World" by Iliffe and Sons Limited
DORSET HOUSE · STAMFORD STREET · LONDON SE1

SenTerCel H.T. RECTIFIERS

from 125V 30mA to 250V 300mA

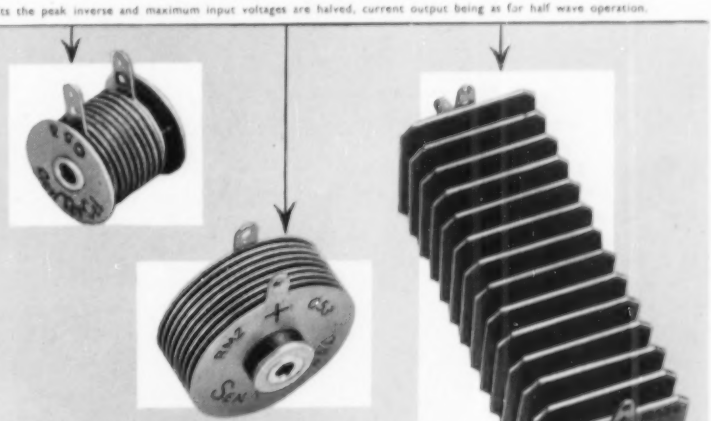
Specially designed for use in domestic Radio & Television receivers, these miniature rectifier stacks nave an established position with manufacturers to whom reliability, small dimensions and low costs are important.



TYPE	RM0	RM1	RM2	RM3	RM4	*RM5
Maximum ambient temperature	35°C 55°C	35°C 55°C	35°C 55°C	35°C 55°C	40°C 55°C	40°C 55°C
Maximum output current (mean)	30mA 15mA	60mA 30mA	100mA 60mA	120mA 90mA	250mA 125mA	300mA 150mA
Maximum input voltage (r.m.s.)	125V	125V	125V	125V	250V	250V
Maximum peak inverse voltage	350V	350V	350V	350V	700V	700V
Max. instantaneous peak current	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Weight	0.82 oz.	1 oz.	1.4 oz.	2 oz.	4.5 oz.	4.75 oz.

* For use in voltage doubler circuits the peak inverse and maximum input voltages are halved, current output being as for half wave operation.

- Instant starting—no warming-up period
- Unlimited instantaneous overload
- No limit to size of reservoir capacitor
- Simple mounting—no valve holder
- Withstand overloads such as charging current of de-formed electrolytic capacitors
- Low heat dissipation
- Practically indestructible in service
- Simple wiring—two connectors only
- Small size ... low weight
- Low cost



SELENIUM SenTerCel RECTIFIERS

Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, London, W.C.2

RECTIFIER DIVISION: EDINBURGH WAY · HARLOW · ESSEX

Telephone : Harlow 26811 Telegrams : SenTerCel, Harlow, Essex

BR. 1102

specially designed for

R.F. HEATING

BR.1102 is a power oscillator for R.F. generators up to 50 kW. Being robust and capable of withstanding severe overloads, this valve is the popular choice for works and factory use.

Full particulars of this valve and its water-cooled counterpart are available on request.

'ENGLISH ELECTRIC'

ENGLISH ELECTRIC VALVE CO. LTD.

Waterhouse Lane, Chelmsford
Telephone: Chelmsford 3491

AP 300/44

WIRELESS ENGINEER

The Journal of Radio Research and Progress

ESTABLISHED 1923

Managing Editor: HUGH S. POCOCK, M.I.E.E. Editor: W. T. COCKING, M.I.E.E.

Technical Consultant: Professor G. W. O. HOWE, D.Sc., LL.D., M.I.E.E.

Editorial Advisory Board:

H. M. BARLOW, B.Sc.(Eng.), Ph.D.(Science), M.I.E.E., M.I.Mech.E. (Pender Professor of Electrical Engineering, University College, London); E. B. MOULLIN, M.A., Sc.D., M.I.E.E. (Professor of Electrical Engineering, University of Cambridge); A. H. MUMFORD, O.B.E., B.Sc.(Eng.), M.I.E.E. (G.P.O. Engineering Department); A. R. A. RENDALL, Ph.D., B.Sc., M.I.E.E. (British Broadcasting Corporation); R. L. SMITH-ROSE, C.B.E., D.Sc., Ph.D., M.I.E.E. (Department of Scientific and Industrial Research)

Volume 33 Number 10

CONTENTS

OCTOBER 1956

National Radio Exhibition 229

Microwave Aerial Testing at Reduced Ranges
by David K. Cheng 234

By-Pass Filters
by R. O. Rowlands, M.Sc. 238

Aerial Pattern Synthesis
by Herbert E. Salzer 240

Low-Frequency Ground Waves
by G. E. Ashwell, B.Sc. and C. S. Fowler 245

Correspondence 251

New Books 251

Standard-Frequency Transmissions 252

Abstracts and References. Nos. 2929-3265 .. A.215-A.238

Published on the fifth of each month

Annual Subscription: Home and overseas £2 9s. 0d.; Canada and U.S.A. $7.50

(Including Annual Index to Abstracts and References)

Published by Iliffe & Sons Ltd.

Editorial, Advertising and Publishing Offices : Dorset House, Stamford Street, London, S.E.1

Telephone: Waterloo 3333 (60 lines) · *Telegrams: Wirenger, Sedist, London*

BRANCH OFFICES AT BIRMINGHAM · MANCHESTER AND GLASGOW

H.F. POWER TRANSFORMERS

H.F. power transformers of outstanding efficiency are the latest additions to the Mullard range of high quality components designed around Ferroxcube magnetic cores.

Utilising the unique characteristics of Ferroxcube to the full, Mullard H.F. transformers are smaller, lighter, and less costly than transformers using alternative core materials. These advantages are particularly marked in transformers required to handle powers of up to 2kW, between the frequency range 2kc/s to 2Mc/s.

Mullard transformers are already finding wide use in applications as diverse as ultrasonic H.F. power generators and aircraft power packs operating from an aircraft's normal A.C. supply. In the latter application, the low leakage field of Ferroxcube can eliminate the need for external screening, thereby reducing the size and weight of the transformer even further.

As with all Mullard high quality components, these H.F. power transformers are designed and built to engineers' individual specifications. Write now for details of the complete range of components available under this service.

RATING . . . . . **UP TO 2 kW**

FREQUENCY RANGE . . . . **2 Kc/s to 2 Mc/s**

Mullard

'Ticonal' permanent magnets
Magnadur ceramic magnets
Ferroxcube magnetic cores

MULLARD LTD • COMPONENTS DIVISION • CENTURY HOUSE • SHAFTESBURY AVENUE • WC2 MC1A

WIRELESS ENGINEER

Vol. 33 OCTOBER 1956 No. 10

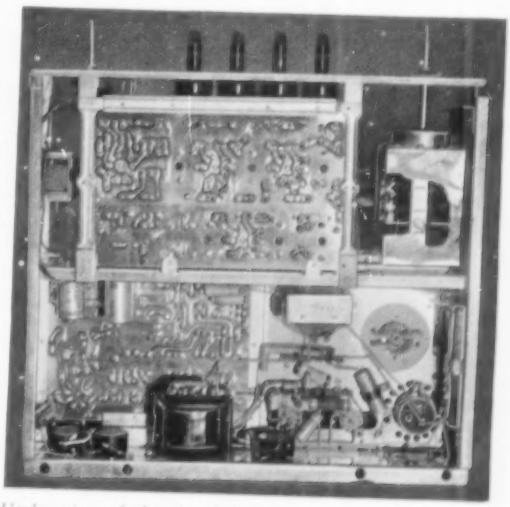
National Radio Exhibition

HELD at Earls Court from 22nd August to 1st September, the National Radio Exhibition was, as usual, confined chiefly to a display of domestic receiving equipment. Television was naturally the most obvious feature of the exhibition, but sound receivers were very prominent, and among them sets for v.h.f. reception of f.m. broadcasting were common. There were, of course, other exhibits. A few component manufacturers were showing, some test equipment was displayed and there were quite a number of electronic items. In none of these fields, however, were the displays as representative of the industry as they were in broadcast apparatus.

It is, perhaps, natural that since the exhibition is one for the public there should be no great show of technicalities. The stress is on appearance and performance and it was more difficult even than usual to see what the inside of a set looks like. There were a few exceptions, of course, and for example, Pam were making a feature of the chassis of one of their television sets, because it embodies a great amount of printed circuitry. Two such assemblies are used and together they cover the greater part of the i.f. amplifiers and the timebases. The tuner is a separate unit which, together with the two printed panels, is carried by the main chassis framework; this also holds the main power-supply components, variable resistors and the larger transformers.

Generally speaking, however, chassis were exhibited but rarely and the general visitor could see little but the cabinet styling and the picture. The use of 21-inch tubes has become general and few firms did not show at least one model of this size. The 17-inch tube, however, is probably the most popular and the 14-inch is very common. Tubes smaller than this are now almost completely obsolete for domestic television, save in one particular application. This is the portable set. Ekco have one, which was first shown last year, with a 9-inch tube and provision for Band II f.m. reception, which can be operated from a car battery. Spencer-West also have a 9-inch model for a.c. supplies which is intended perhaps less as a true portable than as an occasional receiver for the nursery or the sick room. Murphy showed last year a set of this character having a 12-inch tube and this model is being retained. The Pye version has a 14-inch tube and an aerial plugging into the top of the case.

In all these portable sets the cabinet styling is of a simple functional type which is perhaps more properly described by the word case than cabinet. Everywhere else, however, the polished wood



Under view of chassis of Pam 'printed circuit' television receiver.

cabinet holds pride of place. Bush have a 14-inch model with a moulded bakelite case, but the same chassis is available at a higher price in the more conventional wooden cabinet. This firm has for a good many years favoured the bakelite case, and in the past has produced both 9-inch and 12-inch tube models.

There is a definite tendency this year to place the occasional controls in a more accessible position. Instead of being tucked away at the back, they are now often placed at the side and sometimes, even, on the front. The main controls, station selector, fine tuner, brightness and volume, are usually on the front. However, the introduction of table models with a 21-inch tube has resulted in these controls being quite commonly moved to the side of the cabinet, so that the frontal area can be reduced.

Remote control has appeared in a few cases. Ekco have a small unit containing brightness and volume controls which is connected to the set by a cable; it can be plugged in at will without circuit alterations. Philco have a more elaborate system which permits remote station selection; in this a pecking motor is used to control the turret tuner.

Television Circuits

In the general form of circuitry, television sets are exhibiting a marked tendency towards standardization. This is, of course, only in broad outline for there are many detailed differences between the products of different manufacturers. The tuner is invariably a sub-unit with a double-triode cascode r.f. amplifier and a triode-pentode frequency-changer. A single tuned circuit is used for the aerial-feeder-to-first-grid connection and a coupled pair of circuits between the r.f. stage and the mixer. The oscillator is based upon the Colpitts circuit and there are thus four tuned circuits which require alteration for station selection.

G.E.C. console with 21-inch tube.

Philco receiver with 21-inch tube, remote control and Band II f.m.

The turret tuner is the favourite. Each coil assembly forms a separate 'biscuit' mounted in a rotating framework so that the required biscuit can be brought round to a set of spring connectors. An advantage of the turret is its great flexibility, for the biscuits are readily changed. Some twelve can normally be fitted, but as only a few are necessary for British television, there are sufficient blanks to enable Band II coils to be fitted. The television set lends itself to v.h.f. sound broadcast reception and quite a few are arranged for it. Five Band I coils may be fitted with two or three Band III and three for Band II.

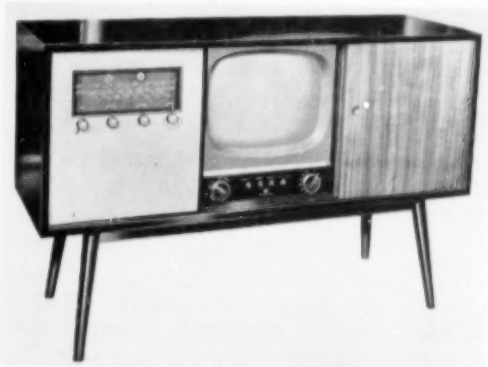
An alternative to the turret is the incremental-inductance tuner. In this some twelve coils are connected in series and the appropriate ones are short-circuited by a multi-way switch. Most of the coils are of very small inductance, merely enough for their insertion to shift the tuning by one channel. This scheme finds a number of supporters, including H.M.V. and Pye. Still another method is adopted by Bush. Virtually continuous tuning with ganged dust-iron cores is adopted; there are two sets of coils, one for each band, with a change-over switch. The control, however, is by a cam with a clicker mechanism. So far as the user is concerned, therefore, all three methods result in his having a control knob with some twelve definite positions for the various channels.

All these tuning methods were adopted last year, if not before, and there is no obvious change in any of them this year. Detail refinement has taken place, however, mainly in improving

signal-noise ratio and uniformity in production.

Nearly everyone has now adopted the standard intermediate frequencies of 34·65 Mc/s for vision and 38·15 Mc/s for sound. The general practice is to use coupled pairs of circuits in both amplifiers with trap circuits for rejecting the sound signal. Three i.f. stages for the vision channel and two for the sound are quite common, but some makers adopt a stage less. There is, perhaps, a tendency for the greater number to be used by those makers who do not market special fringe-area models.

Detectors are invariably diodes, either valve or crystal, and the sound-channel ignition-interference suppressor is also a diode. The vision-channel suppressor may also be a diode but there is quite a tendency to include a triode arranged as a black spotter. It is usually fed with the video signal at its cathode and so biased that it is non-conductive until the signal level exceeds peak white. It then conducts on interference to produce an output signal at its anode in the same phase as the interference in the video output and, because of the amplification, at a somewhat greater level. The signal proper is applied to the cathode of the c.r. tube and the triode output to the grid; the net result is that the triode output tends to predominate in its effect on the tube and the interference tends to produce a black spot rather than a white one, hence the name black-spotter.



Pye V 17 RG with 17-inch tube. The sound receiver covers medium and long waves as well as Band II and gramophone equipment is housed behind the doors on the right.

The video amplifier is invariably a pentode. It is becoming increasingly common to add to it a cathode-follower, however. This is done partly to obtain a lower output impedance, and partly because it results in an increase of amplification. This comes about because the input capacitance of the cathode-follower is much less than that of the c.r. tube plus sync separator plus wiring. Consequently, the coupling resistance of the pentode stage can be increased to such a degree that the higher gain there more than offsets the loss in the cathode-follower itself.

On the sound side a pentode output stage is usual, but in some of the larger sets more attention is being paid to sound quality. A Pye radio cum television cum gramophone set has no less than four loudspeakers. An H.M.V. model has two and is very unusual in that provision is made for the bass speaker to be mounted on either side of the cabinet so that the side which best suits the room acoustics can be chosen.

Bush VHF 61, covering medium and long waves and Band II.

For the line timebase the so-called economy circuit with boost diode is universal. A few makers adopt the direct-drive system, but most include an auto-transformer for feeding the deflector coils. The pentode output valve is driven either by a blocking oscillator or a multivibrator. It appeared last year that there was a strong tendency towards the general adoption of flywheel sync. This year's practice hardly supports this, however; most, if not all, of those manufacturers who adopted it last year have retained it this, but few others have changed over to it.

The fact is that flywheel sync is a necessity in British television only under fringe-area conditions, and many people consider that the simpler direct-locking method is preferable when interference is not serious. It is, of course, also cheaper. Some firms, therefore, consider it desirable to market two models, one of moderate sensitivity with direct-locking for service-area use and another of high sensitivity with flywheel sync for fringe areas.

Other firms think it better to have only a single model and so find it necessary to include flywheel sync to cater for difficult receiving conditions, although it is not necessary for the easier ones.

Murphy is one example of a firm which follows the two-model policy. The normal sets have only two i.f. stages in the vision channel and direct-locking of the line timebase. The fringe-area models have three stages and flywheel sync.

For the frame timebase a blocking-oscillator or multivibrator sawtooth-generator is invariably used and is followed by a pentode output stage feeding the deflector coils through a transformer, or sometimes an auto-transformer. The well-known *RC* feedback circuit is still a favourite for securing linearity of scan. Synchronizing methods vary considerably but there is certainly a tendency to favour ones which embody some measure of integration of the frame sync pulses. The simple integrator, however, is hardly ever used.

Power supplies are usually simple and straightforward, a.c./d.c. technique being general. Valve heaters are connected in series and a half-wave rectifier supplies the h.t. through a simple smoothing circuit involving very large capacitances and a single choke, or even resistance. The e.h.t. supply is invariably taken from the flyback of the line timebase and supplies of up to some 17 kV are obtained for large tubes. Some firms, for example Ekco, connect a Metrosil unit across the e.h.t. supply to obtain a degree of voltage stabilization, but this is not the general practice.

There is a tendency for the focus magnet to disappear. Some of the larger tubes are being made with partial or complete electrostatic focusing. In some cases the control is pre-set or non-existent, but it can be a conveniently-placed potentiometer instead of the rather inaccessible lever which adjusts the permanent magnet of the more conventional set.

Ekco A 274 *Band II f.m. receiver.*

F.M. Reception

It was said earlier that the television set lends itself well to f.m. reception of Band II broadcasting. In part this is because the sound i.f. amplifier is normally of about the right bandwidth for f.m. Provision for f.m. reception requires merely the addition of a discriminator and a pair of diodes to act as a ratio detector. There is, of course, some switching complication. Basically, this is merely a changeover switch to connect the a.f. amplifier to the appropriate detector. However, it is usually desirable to put the purely vision side of the apparatus out of action when only Band II reception is needed, and some power-supply switching is thus included. All these switches are mechanically linked with the turret tuner so that operating the station-selector control automatically makes all the required circuit changes.

Cossor 543 *portable, using a printed circuit.*

Apart altogether from television, receivers equipped for Band II reception are growing in numbers. The basic arrangement is unchanged from last year. This is a standard medium- and long-wave receiver having a triode-heptode frequency-changer, one i.f. stage at around 465 kc/s, diode detector and one or two audio stages. For Band II, 10·7-Mc/s i.f. transformers are added and a ratio detector. The oscillator is put out of action, and the heptode section of the valve turned into an extra i.f. stage. All this is preceded by a Band II tuner comprising a double-triode of which one section functions as a mixer-oscillator and the other as a cathode-input r.f. amplifier. There are, of course, various detail differences between sets, but almost all use this basic arrangement. A few sets, rather more than last year, give Band II reception only, notably Ekco, who have three such models.

Aerials

Broadcast sets do now generally include internal aerials. The use of a ferrite-rod aerial for the medium and long wavebands is very common and either a compressed dipole or a capacitance plate for Band II. Provision for the connection of an external aerial is made, for the internal ones can naturally be wholly satisfactory only in areas of high field strength.

For television, internal aerials are not common, although some of the portable types have rod or similar aerials attached to them. In one form or another, however, the loft or outdoor dipole reigns supreme and is generally combined with a reflector and, possibly, one or more directors to form a Yagi.

Most of the complications arise from the need for an aerial to operate on both Bands I and III.

A favourite arrangement of the simpler type is a Band I dipole fitted with stub elements which, in effect, make it resonant in both bands. To this are added a Band III reflector and one or two directors, so that the assembly functions as a simple dipole on Band I and as a Yagi on Band III.

An alternative is adopted by J.B. Aerials, for in this there is a square frame with sides of a length resonant in Band III. This is mounted vertically and broadside on to the transmitter, and it is fed at the middle of the top and bottom elements through V arms, also resonant in Band III. At these junctions of the square and V vertical Band I rods are fitted.

A disadvantage of the conventional form of aerial is that the average loft is not large enough to contain a Band I array. Commonly some form of compression, such as by bending the ends, is used, but this naturally reduces the efficiency somewhat. A new form is the Labgear Bi-Square. There are two rods spaced a quarter-wave apart each bent to form a square one wavelength in periphery. One square is mounted broadside on to the transmitter and the other is behind it to act as a reflector. The driven element is fed at the centre of one of the vertical sides (for vertical polarization), and the reflector has a stub connected in series with each of its vertical sides at their centres in order to provide proper phasing.

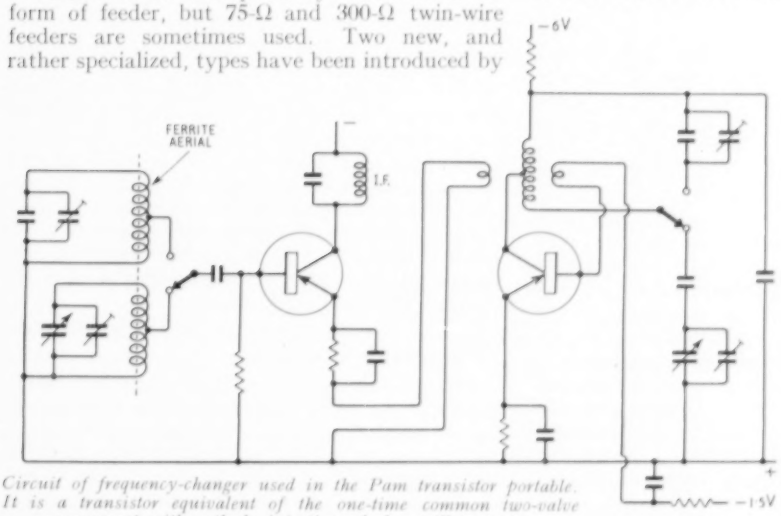
For Channel I the dimensions are roughly 5 ft square and 4 ft back to front, the impedance is 75 Ω and it is claimed that the gain is 12 dB over a plain dipole.

Coaxial cables are probably the commonest form of feeder, but 75-Ω and 300-Ω twin-wire feeders are sometimes used. Two new, and rather specialized, types have been introduced by Aerialite. One is a normal 75-Ω coaxial cable, but with a galvanized-steel wire embedded in the outer p.v.c. covering to act as a mechanical support on a long run. The other is again a more or less normal coaxial cable, but with polyethylene over the outer conductor and a second outer outside this. It is thus a double-screened coaxial cable and is intended for use where exceptionally good screening is needed.

H.M.V. 1360 transportable for a.c./d.c. operation, covering long, medium and short waves.

Transistor Applications

To return to receivers, several portables have made their appearance in which the transistor has completely replaced the valve. Printed-circuit technique has also been introduced for them. The Pam 710 has in all eight transistors. There are a separate oscillator and mixer, two i.f. stages at 315 kc/s, a detector, an a.f. stage and a push-pull output stage. The i.f. stages are neutralized. Transformer coupling is used to the output stages but not from it, for the loudspeaker has a centre-tapped speech coil of some 120-Ω impedance. The battery supply is at 6 V.



Circuit of frequency-changer used in the Pam transistor portable. It is a transistor equivalent of the one-time common two-valve arrangement with cathode injection of the oscillator voltage.

The Cossor transistor set is somewhat different and has six transistors, the first functioning as a mixer-oscillator. There is only one i.f. stage, at 460 kc/s, and there is an a.f. stage followed by a pair of drivers for the push-pull output stage.

The transistor is also being widely used in portable record reproducers. A 6-V dry battery not only provides power for the amplifier but operates the motor-driven turntable for 45-r.p.m.

records. Cossor, Philco, Philips, Pye and Vidor all showed examples of this type of equipment.

Mullard demonstrated some of the things to come in possible future applications of the transistor, the apparatus shown including types of transistor not yet on the market. One was a class A push-pull amplifier with an output of 4 W at less than 0·4% distortion and a power supply of 12 V. Another was a Band II f.m. receiver utilizing an avalanche transistor as an r.f. oscillator, its tenth harmonic being picked out for frequency-changing purposes.

Ferguson 377 RG radio-gramophone with three loudspeakers.

Much more in accord with the present, and a thing which is more practicable as a production possibility of today was a car-radio receiver using push-pull transistors for the output stage and a 12-V power supply. The early stages were all valves, but valves developed to operate with a 12-V h.t. supply. This arrangement thus combines the power efficiency of the transistor for the output stage with the efficiency of the valve at high frequencies, and has the merit of making any h.t. supply equipment unnecessary. It is a line of attack of particular interest.

MICROWAVE AERIAL TESTING AT REDUCED RANGES

By David K. Cheng

(Electrical Engineering Department, Syracuse University, Syracuse, New York)

SUMMARY.—The far-zone distance needed for taking radiation patterns of microwave aerials with large aperture dimensions at very high operating frequencies is often not available on an average test site. It is a general practice in such cases to defocus the primary source along the principal axis of the reflector by a small distance so that Fraunhofer patterns may be simulated in the Fresnel zone. This paper presents three different approaches with which the proper amount of defocus may be determined. The results are plotted and compared.

Introduction

IN testing microwave aerials, it is essential that radiation-pattern measurements be made in the far zone (Fraunhofer region) of the aerial assembly. While there is no clear-cut boundary line between the far zone and the quasi-near zone (Fresnel region), the usual rule-of-thumb criterion is that $2D^2/\lambda$ represents a safe far-zone distance, where D is the maximum dimension of the aerial aperture and λ is the operating wavelength. At a distance of $2D^2/\lambda$ the maximum path-length difference between the contribution from the edge of the aperture and that from the centre corresponds to $\pi/8$ or 22·5°. In practice, an unobstructed open space with a dimension of $2D^2/\lambda$ is often not available for testing high-gain aerials operating at microwave frequencies. For example, the $2D^2/\lambda$ distance for a 10-foot aerial at 3 cm would be about 2,030 feet. Higher gain requirements would demand even larger test sites. The need for the technique of testing microwave aerials at a closer distance with acceptable accuracy is therefore both real and urgent.

This paper begins with a résumé of the method used in contemporary practice of defocusing the primary feed in order to make radiation-pattern measurements at reduced ranges. Two new approaches, one from the consideration of the aperture phase and the other from the consideration of an ellipsoidal reflector, are then presented. Formulae relating the proper amount of defocus and the distance of measurement are given and the results obtained by the three different methods are critically compared.

MS accepted by the Editor, October 1955

Geometrical Approach

It is a well-known fact that, for a given primary source of excitation, a best radiation pattern will be obtained from a paraboloidal reflector at a field point in the far zone when the source is located at the focal point of the reflector. Geometrically this may be explained by equal path-length from the source to all points in an aperture

plane by virtue of the inherent property of a focused paraboloid. If the field point is far enough away from the reflector, the path-lengths from the aperture points to the field point will again be approximately equal, resulting in an optimum additive effect. When the field point lies in the quasi-near zone, the path-length differences from the points in an aperture plane to the field point must be compensated in some way in order that the measured radiation pattern may approach the true far-zone pattern. This is done by slightly defocusing the source along the reflector axis in the direction away from the reflector. Since the amount of on-axis defocus is the only adjustable variable here, one cannot expect to achieve equal path-lengths for all points in the aperture plane. For simplicity, the conventional approach is to make the path-length from the source to the field point by way of the apex of the paraboloid equal to that by way of the points on the edge of the reflector.

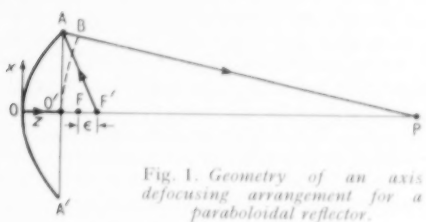


Fig. 1. *Geometry of an axis defocusing arrangement for a paraboloidal reflector.*

In Fig. 1, a cross section of a symmetrical paraboloidal reflector, AOA′, is shown along with the focal point F and a field point P. Let

$$A\,O' = O'\,A' = D/2$$
$$O'\,P = B\,P = R$$

The path-length difference from points A and O′ in the aperture plane to the field point P is then AB, which can be determined as follows:

$$A\,O'^2 + O'\,P^2 = A\,P^2 = (AB + BP)^2$$

or

$$(D/2)^2 + R^2 = (AB + R)^2 \quad .. \quad .. \quad (1)$$

When AB^2 is neglected in comparison with R^2, which is a very good approximation, (1) gives

$$AB = D^2/8R \quad .. \quad .. \quad (2)$$

The requirement of equal total path-length from the source point to the field point by way of the points A and O′ then can be satisfied by moving the source point to F′ such that

$$(F'\,O + O\,O') = F'\,A + A\,B \quad .. \quad (3)$$

Let the focal length $OF = f$ and the amount of defocus $FF' = \epsilon$, then

$$O\,O' = D^2/16\,f$$

$$F'\,A = \sqrt{\left[\epsilon + \left(f - \frac{D^2}{16f}\right)\right]^2 + \left(\frac{D}{2}\right)^2}$$

and substitution in (3) yields

$$\epsilon = \frac{f^2}{R}\left[\left(\frac{R}{R-f}\right) + \left(\frac{D}{4f}\right)\right] \quad .. \quad (4)$$

When $(f/R)^2 << 1$, it is accurate enough to write (4) as

$$\epsilon = \frac{f^2}{R}\left[1 + \frac{f}{R} + \left(\frac{D}{4f}\right)^2\right] \quad .. \quad (5)$$

Normalizing all quantities with respect to the focal length and introducing new notations $\epsilon' = \epsilon/f$, $R' = R/f$, and $D' = D/f$, one can rewrite (5) as

$$\epsilon' = \frac{1}{R'}\left[1 + \frac{1}{R'} + \left(\frac{D'}{4}\right)^2\right] \quad .. \quad .. \quad (6)$$

The normalized amount of defocus needed is seen to increase when R' decreases and when D' increases. As R' approaches infinity, ϵ' correctly goes to zero.

Aperture-Phase Approach

Relation (6) was derived solely from the laws of geometrical optics; it does not impose any restriction on R other than $(f/R)^2 << 1$. The problem can also be approached from the consideration of the phase distribution in an aperture plane of the reflector together with the diffraction integral for the field at a point in space.

When the point under consideration is in the quasi-near zone (Fresnel region) of a paraboloidal reflector, the normalized diffraction integral which gives the field pattern in a horizontal plane can be approximated as[1]

$$I(u) = \int_0^1 F(r)\, e^{[-jk\,D^2r^2/8R]}\, r\, J_0(ur)\, dr \quad (7)$$

In (7), r is the radial dimension of the aperture plane normalized with respect to $D/2$; $u = (\pi D/\lambda) \sin\theta$, θ being the azimuth angle; $k = 2\pi/\lambda$; and $F(r)$ is the circularly symmetrical amplitude illumination function over the aperture. The explicit exponential term is the Fresnel-zone contribution; terms above the second order are neglected. When R is very large, (7) reduces to the far-zone pattern function

$$I_0(u) = \int_0^1 F(r)\, r\, J_0(ur)\, dr \quad .. \quad (8)$$

With $R = 2D^2/\lambda$, the exponent $-jk\,D^2r^2/8R$ equals $-j\,\pi r^2/8$ which yields the expected maximum phase difference $\pi/8$ at the edge ($r = 1$).

When the primary source is displaced from the focus of a paraboloidal reflector along the reflector axis in the direction away from the reflector with a view to simulating far-zone patterns in the quasi-near zone, there will be a relative phase

[1] S. Silver, "Microwave Antenna Theory and Design", M.I.T. Radiation Laboratory Series, Vol. 12, Chapter 6, 1949, McGraw-Hill Book Co., Inc., New York, N.Y.

variation over the aperture. This phase variation referred to the centre point is found with good approximation to be[1]

$$\delta = -\frac{2\epsilon}{1+\left(\frac{D}{4f}\right)^2 r^2} = -2\epsilon\left\{1-\frac{r^2}{\left(\frac{4f}{D}\right)^2+r^2}\right\} \quad .. \quad .. \quad (9)$$

The diffraction integral now becomes

$$I(u) = \int_0^1 F(r)\ e^{jk[\delta - D^2r^2/8R]}\ r\ J_0(ur)dr \quad .. \quad (10)$$

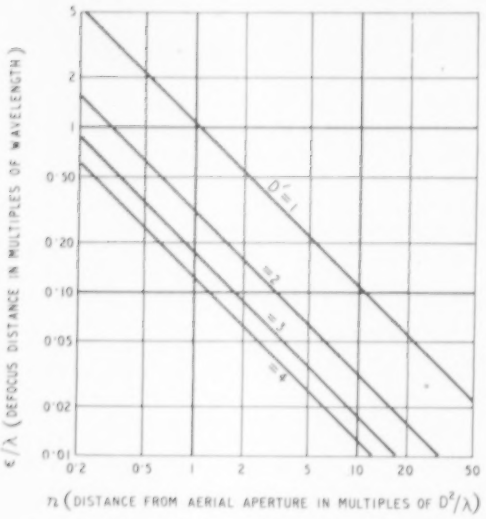


Fig. 2. *Defocus chart from aperture-phase viewpoint.*

The integration in (10) is difficult to carry out. However, comparison with the far-zone integral (8) reveals that ϵ should be chosen to make the exponent in (10) vanish or equal to a constant. Unfortunately this cannot be done exactly for all values of r because of the manner in which the exponent varies with r. A simple way of effecting this is to approximate δ in (9) with a function of the type $(a + br^2)$ where both a and b may involve ϵ. a, being independent of the variable of integration r, does not affect the normalized radiation pattern; the required amount of defocus can then be determined from the equation

$$b = \frac{D^2}{8R} \quad .. \quad .. \quad .. \quad .. \quad (11)$$

It has been found[1] that an acceptable and convenient approximation for δ is

$$\delta \approx -2\epsilon\left\{1-\frac{r^2}{\left(\frac{4f}{D}\right)^2+1}\right\} \quad .. \quad (12)$$

[1] S. T. Moseley, "On Axis Defocus Characteristics of the Paraboloidal Reflector", Final Report for Contract No. AF 30(602)-925, Syracuse University Research Institute, August 1954.

(12) is exact for $r = 0$ (centre) and $r = 1$ (edge of aperture). For other values of r, the δ given by (12) is slightly larger than that given by (9); the error decreases when the (f/D) ratio of the reflector increases. (12), in conjunction with (11), gives

$$\frac{\epsilon}{f} = \frac{f}{R}\left[1+\left(\frac{D}{4f}\right)^2\right]$$

or

$$\epsilon' = \frac{1}{R'}\left[1+\left(\frac{D'}{4}\right)^2\right] \quad .. \quad .. \quad (13)$$

which checks with (6) when $R' = R/f >> 2$. If it is desirable to write

$$R' = nD'^2/\lambda' \quad .. \quad .. \quad .. \quad (14)$$

with $\lambda' = \lambda/f$, n a numeric, then (13) reduces to

$$\frac{\epsilon'}{\lambda'} = \frac{\epsilon}{\lambda} = \frac{1}{n}\left[\left(\frac{1}{D'}\right)^2+\left(\frac{1}{4}\right)^2\right] \quad .. \quad (15)$$

It is obvious from (15) that for a given value of D', (ϵ/λ) plotted versus n gives a hyperbola in linear scales, and a straight line in log-log scales. Fig. 2 shows a set of parallel straight lines in log-log scales corresponding to several different values of D'. For a given reflector, the required amount of defocus to simulate far-zone patterns at a given distance is readily determined from these lines. It is noted that for $n = 2\ (R = 2\,D^2/\lambda)$, appreciable defocus is still necessary, the required amount being larger for smaller D'.

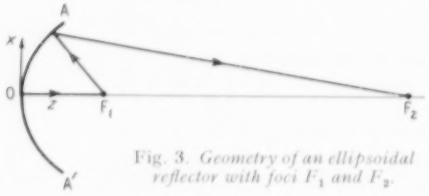


Fig. 3. *Geometry of an ellipsoidal reflector with foci F_1 and F_2.*

Ellipsoidal-Reflector Approach

The purpose of defocusing the primary source in the case of a paraboloidal reflector is to simulate far-zone radiation patterns at points in the quasi-near zone. In terms of geometrical optics, it is quite easy to see that this could be achieved by means of an ellipsoidal reflector. If the primary source is placed at one of the two foci of the ellipsoid, the reflected rays will converge at the other.

Let the reflector AOA′ in Fig. 3 be a cross section of an ellipsoid with focal lengths $OF_1 = f_1$ and $OF_2 = f_2$. Its equation in the xz-plane is then

$$z = \frac{f_1+f_2}{2}\left\{1-\sqrt{1-\frac{x^2}{f_1 f_2}}\right\} \quad .. \quad (16)$$

Subject to the condition

$$\sqrt{1-\frac{x^2}{f_1 f_2}} \approx 1-\frac{x^2}{2 f_1 f_2} \quad .. \quad .. \quad (17)$$

(16) can be approximated as

$$z=\frac{f_1+f_2}{4 f_1 f_2} x^2 \quad .. \quad .. \quad .. \quad (18)$$

which is the equation for a parabola of focal length

$$f=\frac{f_1 f_2}{f_1+f_2} \quad .. \quad .. \quad .. \quad .. \quad (19)$$

or

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2} \quad .. \quad .. \quad .. \quad .. \quad (20)$$

Hence, for reflected rays to converge at $R=f_2$, the primary source should be placed at $z=f_1$, and

$$\epsilon=f_1-f=\frac{f_1^2}{f_1+f_2} \quad .. \quad .. \quad (21)$$

Solving (19) or (20) for f_1 and substituting the result in (21), one obtains

$$\epsilon=\frac{f^2}{f_2-f}=\frac{f^2}{R-f} \quad .. \quad .. \quad (22)$$

or, in normalized form,

$$\epsilon'=\frac{1}{R'-1}=\frac{1}{R'}\left[1+\frac{1}{R'}+\frac{1}{R'^2}+\cdots\right] \quad (23)$$

(23) should be compared with both (6) and (13).

An examination of (17) shows that it implies the condition $(1/8)\left(\frac{x^2}{f_1 f_2}\right)^2 << 1$. Now the maximum value of x is $D/2 \leqslant 2 f_1$. This reduces the condition to

$$\frac{f_2}{f_1} >> \sqrt{2} \quad .. \quad .. \quad .. \quad .. \quad (24)$$

which is undoubtedly true in practice. An ellipsoidal reflector with focal lengths f_1 and f_2 has its semi-major and semi-minor axes equal to $(f_1+f_2)/2$ (arithmetical mean) and $\sqrt{f_1 f_2}$ (geometrical mean) respectively; it approaches very closely a paraboloidal reflector when (24) is satisfied. As an example, with $f_2=R=10 f_1$, the maximum error introduced by (17) is about 3% and with $f_2=R=50 f_1$, the maximum error is less than 0·09%.

Comparison of Defocusing Methods

Curves plotting ϵ' versus R' based upon equations (6), (13), and (23) from the three different approaches discussed above are shown in Fig. 4. It is seen that except for small values of R', the required ϵ' from the geometrical approach is nearly the same as that from the aperture-phase approach, both of which increase with increasing D'. The required ϵ' from the ellipsoidal-reflector approach is the smallest of the three methods and is independent of D'.

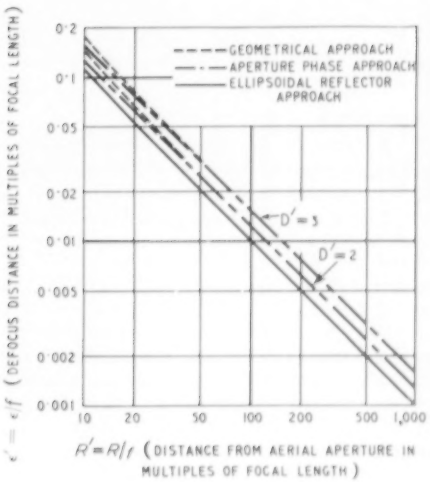


Fig. 4. *Comparison of defocusing methods.*

A review of the geometrical approach reveals that there is really no plausible justification for requiring equal path-length from the source to the field point by way of the apex and by way of the points on the edge of the paraboloidal reflector only; the path-lengths by way of the intermediate points on the reflector would then all be longer. The approximation (12) used in the aperture-phase approach is exact also for $r=0$ and $r=1$ only. For $0<r<1$, δ given by (12) is numerically too large, resulting in an ϵ' which is also too large. Although these two approaches yield approximately the same results, the aperture-phase approach makes it clear that this method would not be useful when R is too small because it would then be necessary to include terms higher than the second order in the exponent of (7); the geometrical approach gives no indication of this restriction. It is believed that ϵ' in (23) derived from the ellipsoidal-reflector approach gives the most nearly correct results because the approximation implied by (17) is very good; it does not restrict its correctness only to the edge of the reflector.

It should be noted that in all three methods the required amount of defocus is not a function of the operating wavelength and that diffraction phenomena are neglected.

BY-PASS FILTERS

By R. O. Rowlands, M.Sc., A.M.I.E.E.

(*B.B.C. Engineering Training Department*)

SUMMARY.—By-pass filters are described having three pairs of terminals and in which all frequencies are passed, without distortion, between two of the pairs but only a limited band of frequencies is transmitted between either of these pairs and the third pair of terminals.

Introduction

WHEN two terminal stations are connected by telephone line carrying voice frequencies and carrier channels, it sometimes occurs that there are, on the route, a number of wayside substations who wish to have facilities for communicating with either of the terminal stations or with each other. The problem arises of how to connect them to the line cheaply and with the minimum of interference to the carrier circuit. In the past, the solution has been to provide a filter consisting of two complementary high- and low-pass filters connected back to back, and to connect the substation to the junction of the two low-pass filters.

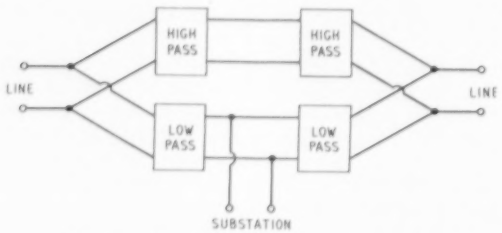


Fig. 1. *Usual by-pass filter arrangement.*

A typical arrangement is shown in Fig. 1. The input impedance of the substation telephones is high in the rest position but is otherwise equal to that of the line. Consequently the signals pass straight through the filters except when a substation comes on, in which case part of the low-frequency power is absorbed. A disadvantage of this method is that filters designed on the image-parameter basis have an appreciable amount of attenuation at the cross-over point and, when a large number of these filters are connected in tandem, the degree of sideband cutting may be excessive. Again, since the function of the high-pass filter is not to provide attenuation but merely to match the impedance of the unit to that of the line, the number of components involved is somewhat excessive. Analysis shows that a better solution may be obtained by designing the filter on a different basis.

MS accepted by the Editor, November 1955

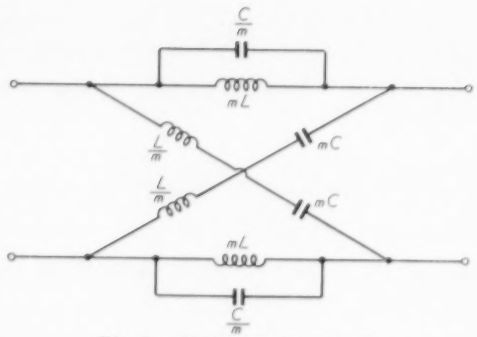


Fig. 2. *All-pass lattice network.*

The All-Pass Network

Type 1

The lattice shown in Fig. 2 is an all-pass network as the antiresonant frequency of the series arms coincides with the resonant frequency of the shunt arms. If the capacitors in the series arms are regarded as bridging the network, the remainder has the configuration of a low-pass filter and may be expanded into the form of a ladder. The circuit will now be as shown in Fig. 3 and fulfils the requirements of a by-pass filter, namely that it has a constant resistive impedance at all frequencies and passes all frequencies without attenuation, the low frequencies going through the low-pass filter portion and the high frequencies being by-passed by the series capacitors. The

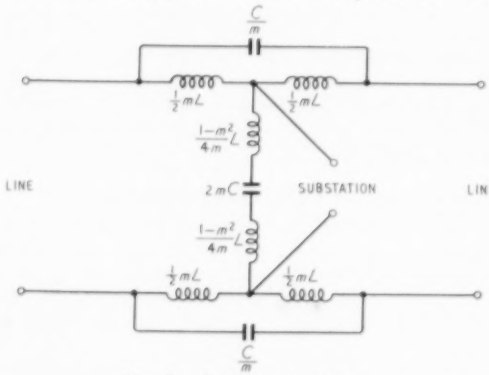


Fig. 3. *By-pass filter type* 1.

substation may be connected to the middle of the low-pass section and so will receive just under half the power available at this point. The carrier circuit will not be affected. The high-pass section of the filter, consisting of two capacitors, is of the simplest form possible. A typical performance curve for a filter with m equal to 0·6 is shown in Fig. 4.

The design formulae are,

$$L = \frac{R}{2\pi f} \qquad C = \frac{1}{2\pi f R} \qquad m = \sqrt{1 - \frac{f^2}{f_\infty{}^2}}$$

Where R = the impedance of the line
f = the cut-off frequency of the low-pass filter
f_∞ = the frequency of peak attenuation

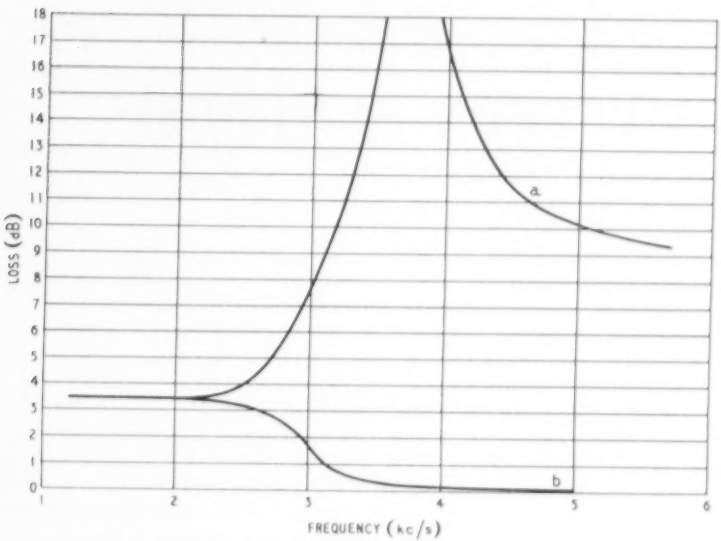


Fig. 4. *Performance of network type 1; curve (a) line to substation, curve (b), line to line with substation connected. The line-to-line loss with no substation in circuit is negligible at all frequencies.*

If, in a particular application, the high-frequency loss between the line and substation terminals of the network is insufficient, resulting in the carrier sideband breaking through at an intolerable level, an improvement may be obtained by connecting an extra low-pass filter section in the substation circuit provided, of course, that this filter may be disconnected when the substation is not in use, otherwise it will alter the all-pass characteristic of the network in this condition.

If it is not possible to have a filter in the substation circuit, which may be disconnected at will, then a network type 2 may be used instead of type 1 to give the extra protection required.

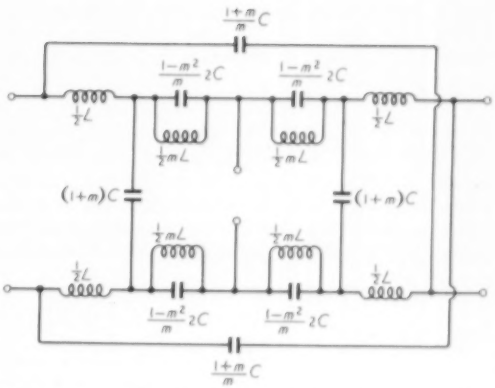


Fig. 5. *By-pass filter type 2.1.*

Type 2

If, in a particular application, the low-pass section does not attenuate the carrier-circuit frequencies to a sufficient degree, a more complex filter may be derived from the all-pass network having three elements in each lattice arm. This may be developed into a by-pass filter in either of the two ways shown in Figs. 5 and 6. It will be seen that, in order to expand the low-pass section into a ladder, the bridging capacitor must appear across the lattice arm of the filter. The design formulae are the same as for type 1 except that,

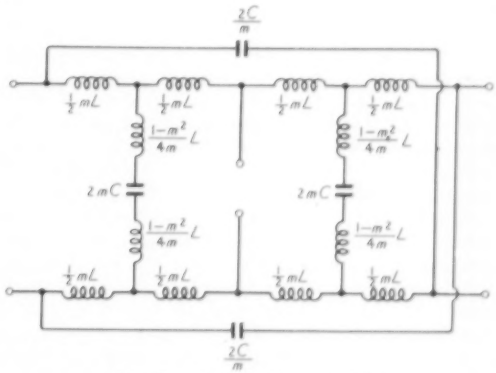


Fig. 6. *By-pass filter type 2.2.*

in this case, the impedance of the low-pass section is different from that of the complete all-pass section. If R is the impedance of the low-pass filter section, the line impedance is $\frac{m}{1+m} \cdot R$ for the filter of Fig. 5 and $\frac{m}{1+m^2} \cdot R$ for the filter of Fig. 6. As m is less than unity, the line impedance is less than the filter impedance at the T-off point. This may be an advantage as the substation will then absorb more of the available power.

Dual Circuits

To each of the networks described there exists a dual network in which the high frequencies appear at the third pair of terminals, instead of the low frequencies, as in the networks so far described. An example of the dual of the all-pass network type I is given in Fig. 7. These dual networks might find possible use in communication and signalling circuits on power lines.

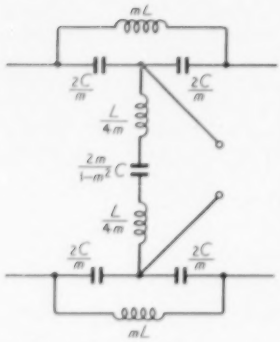


Fig. 7. *Dual of by-pass filter type* I.

Acknowledgment

Acknowledgment is made to the Chief Engineer of the B.B.C. for permission to publish this article.

AERIAL PATTERN SYNTHESIS

Use of Poisson's Formula

By Herbert E. Salzer

(Convair Astronautics, San Diego, California, U.S.A.)

(This work was done while the author was employed at the Diamond Ordnance Fuze Laboratories, Washington, U.S.A.)

SUMMARY.—In the employment of linear arrays in aerial design, one of the important problems of pattern synthesis is to obtain feeding coefficients which will produce very sharp beams. Although optimum patterns are obtained from the Dolph-Tschebyscheff distributions, the numerical work in determining the feeding coefficients mounts as the number of sources increases. This article indicates an entirely independent method of finding feeding coefficients, which uses only one very special case of a general formula due to Poisson, to obtain extremely sharp patterns for broadside arrays. Although the resulting formulae are not as flexible as the Dolph-Tschebyscheff formulae and require a comparatively large number of sources, the amplitudes of the feeding coefficients are given at once by an extremely simple explicit expression, which is just as easy to calculate for a formula with over a hundred terms as for a formula having just a few terms (and these amplitudes of the feeding coefficients for broadside arrays are invariably positive).

IN the employment of linear arrays in aerial design, one of the important problems of pattern synthesis is to obtain feeding coefficients which will produce very sharp beams. Although optimum patterns are obtained from the Dolph-Tschebyscheff distributions, the numerical work in determining the feeding coefficients increases with the number of sources. The purpose of this article is to indicate an entirely independent method of finding feeding coefficients, which uses only one special case of a general formula due to Poisson, to obtain extremely sharp patterns for broadside arrays.

The reader is warned that this present paper furnishes only a mathematical solution to the problem of finding a close approximation to a very sharp curve by a cosine series, and its results may need still further consideration before practical use in aerial design.

The resulting formulae have the following three possible disadvantages when compared with the Dolph-Tschebyscheff formulae:

(1) They are not optimum.

(2) Unlike the Tschebyscheff polynomials, where for a prescribed number of sources a single polynomial serves as the basis for calculating feeding coefficients for all variations in the ratio between d and λ, where d = distance between sources and λ = wavelength (e.g., for n odd, $d < \lambda/2$, by Riblet's method), here each expression obtained is used for a fixed ratio of d to λ.

(3) They require the use of a comparatively large number of sources, and so may have restricted applicability at the present time.

But these new formulae have the following four important advantages:

(1) The amplitudes of the feeding coefficients are given at once by an extremely simple explicit expression which is just as easy to calculate for a formula with over a hundred terms as for a formula having only a few terms.

MS accepted by the Editor, June 1955

(2) Formulae which compare favourably with optimum ones can be constructed.

(3) The amplitudes of the feeding coefficients for broadside arrays are invariably positive.

(4) After one has developed the knack of choosing the required constants, even though Poisson's formula is not as adaptable as the Tschebyscheff polynomials for use with pre-assigned d and λ, considerable variations are possible which cover a wide range of the d to λ ratio.

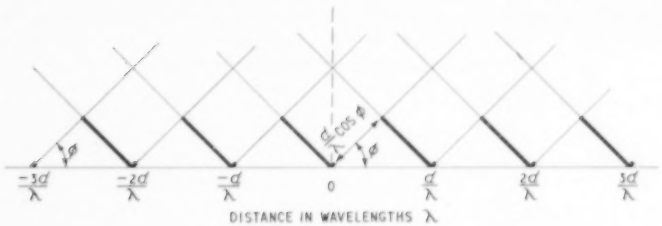


Fig. 1 (left). *System of reference for an array.*

Fig. 2 (below). *Forms of aerial beam.*

Poisson's general formula[1] is expressed by

$$\sqrt{\beta}\left\{\tfrac{1}{2}F_c(0)+\sum_{n=1}^{\infty}F_c(n\beta)\right\} = \sqrt{\alpha}\left\{\tfrac{1}{2}f(0)+\sum_{n=1}^{\infty}f(n\alpha)\right\} \quad .. \quad .. \quad (1)$$

where

$$\alpha\beta = 2\pi,\ \alpha > 0, \text{ and } F_c(u) = \sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos ut\ dt$$

is known as the *Fourier cosine transform* of $f(t)$. If in (1) we let $f(t) = e^{-t^2/2}\cos kt$, then $F_c(u)$ becomes $\exp.\ [-(k^2+u^2)/2]\cosh ku$. This last relation follows immediately from the definite integral formula

$$\int_0^{\infty}\exp.\ [-a^2x^2]\cos bx\ dx = \frac{\sqrt{\pi}\ \exp.\ [-b^2/4a^2]}{2a},\ a>0 \quad .. \quad .. \quad (2)$$

by letting $a^2 = 1/2$ and $b = k+u$ or $k-u$. Then from (1), we get

$$\sqrt{\beta}\exp.\ [-k^2/2]\left(\tfrac{1}{2}+\sum_{n=1}^{\infty}\exp.\ [-\beta^2n^2/2]\cosh k\beta n\right) = \sqrt{\alpha}\left(\tfrac{1}{2}+\sum_{n=1}^{\infty}\exp.\ [-d^2n^2/2]\cos k\alpha n\right) \quad .. \quad (3)$$

Formula (3) is essentially Jacobi's familiar imaginary transformation[2,3,4] which is also used to calculate the error function of a complex variable[5].

The purpose of the discussion in this paper is to show how by judicious choice of the quantities k and β in (3) (the α is determined from β by $\alpha = 2\pi/\beta$), the left member of (3) may be closely approximated by a reasonable number of terms of the right member, in which, if considered as a series of the form $\Sigma a_n \cos nc$, the a_n, $n \neq 0$, corresponds to twice the amplitude of the feeding coefficient of a single point source which is one of a pair of symmetrically situated point sources corresponding to the $\cos nc$ term, for a linear broadside array. Furthermore, the choice of the k and β will be such as to yield a very sharp pattern for the sum of that number of cosine terms.

In all this discussion it is most convenient to work with only pure numbers, to which any problem in finding feeding coefficients, can be reduced. But Fig. 1 will recall to the reader the system of reference of the angle ϕ which denotes the beam angle when there is an odd number of symmetrically situated point sources for a linear broadside array, and the sources are at a distance d apart.

To illustrate this method we work through an example taking an extreme case, where over a 180° range of the angle ϕ, say from 0° to 180°, we desire to produce a very sharp beam at $\phi = 90°$. The total width of the beam is to be only 2·5° and the plotted height is to be completely negligible (i.e., only around 1% or so of the maximum height) everywhere else between 0° and 180°. This is much sharper than the commonly used beams which, when plotted as functions of $t = \cos\phi$, are allowed to widen out away from the t-axis, something like Fig. 2 (a) in shape, whereas here we seek something more like Fig. 2 (b). In the approximate sum $\Sigma a_n \cos nc$, the quantity $c = C\cos\phi$, and if we denote $\cos\phi$ by t, the range of t is from -1 to $+1$. Now the array problem here considered is to find a series of reasonable length, of the form $\Sigma a_n \cos Cnt$* which shall be close to 0 for nearly all values of t between -1 and 1, but which shall increase to 1 within a small range of t corresponding to the 2·5° range in ϕ. The broadside position of the lobe, or the occurrence of the sharp peak at $\phi = 90°$, and the total width of 2·5° for the lobe, correspond to a total width of 0·04 in the argument t, at $t = 0$

*$C = 2\pi d/\lambda$ (See Fig. 1)

or, in other words, since $\Sigma a_n \cos Cnt$ is an even function of t, in the range $t = 0$ to 0·02 (i.e., 1·25° in ϕ), we want $\Sigma a_n \cos Cnt$ to drop from 1 down to around 0·01 and to stay no larger than around 0·01 in the entire range of $t = 0$·02 to 1.

The appearance of equation (3) suggests that we can obtain such a curve from a series of the form $\Sigma a_n \cos Cnt$. We first write down (3) again after multiplying through by $2/\sqrt{\beta}$ for convenience sake:

$$\exp.[-k^2/2]\left(1 + 2\sum_{n=1}^{\infty} \exp.[-\beta^2 n^2/2] \cosh k\beta n\right)$$

$$= \left(\frac{\alpha}{\beta}\right)^{1/2}\left(1 + 2\sum_{n=1}^{\infty} \exp.[-\alpha^2 n^2/2] \cos k\alpha n\right) \quad (3')$$

Now the simplest type of function that is 1 at $t = 0$ and then falls down to 0 and remains small is e^{-t}. But, in order to decrease for negative as well as positive values of t, we should need something like exp. $[-t^2]$. But exp. $[-t^2]$ itself does not become small until t is considerably larger than 1, whereas we want a function that becomes and remains small even when $t = 0$·02. Thus instead of exp. $[-t^2]$ we need something like exp. $[-At^2]$ where A is a large positive constant. This suggests the identification of this exp. $[-At^2]$ with exp. $[-k^2/2]$ in the left member of (3′). The question arises as to whether for a certain judicious choice of β, the combination of k and β will cause all the terms inside the summation on the left side, of the form $2 \exp.[-(k^2 + \beta^2 n^2)/2] \cosh k\beta n$, to be negligible by comparison with the exp. $[-k^2/2]$ term, so that the left side is essentially the solitary exponential exp. $[-k^2/2]$ to within 1% accuracy. Of course, by making the β as large as one wishes, for every n the quadratic part of the exponent in each term, namely the $-\beta^2 n^2/2$ can be made arbitrarily larger in absolute value than the linear part of the exponent, namely $+ k\beta n$ or $- k\beta n$ in the $\cosh k\beta n$, so that

$$2\sum_{n=1}^{\infty} \exp.[-\beta^2 n^2/2] \cosh k\beta n$$

becomes as small as one wishes. However, in practice we do not have such an unrestricted choice of β because too large a choice of β gives rise to such a small value of $\alpha = 2\pi/\beta$ that too many terms will be needed in the right member of (3′) before the factor exp. $[-\alpha^2 n^2/2]$ becomes sufficiently small. In other words, we want an n_0 that is not too large so that all terms for

$$n > n_0 \left(\text{i.e., } 2\left(\frac{\alpha}{\beta}\right)^{1/2} \sum_{n=n_0+1}^{\infty} \exp.[-\alpha^2 n^2/2] \cos k\alpha n\right)$$

may be neglected. Finally, the choice of k and β must yield a product $k\alpha$ that falls within an attainable ratio of d to λ.

It turns out that we can meet all of the above-mentioned conditions by taking $k = 50\sqrt{10}t$ and $\beta = 320$. The choice of $k = 50\sqrt{10}t$ makes the first term in the left member of (3′) equal to exp. $[-12{,}500t^2]$, which is equal to 1 for $t = 0$ and drops down to $e^{-5} < 0{\cdot}01$ even before $t = 0{\cdot}02$ and, of course, remains very close to 0. To show next that the choice of $\beta = 320$ enables us to neglect all the remaining terms of the left member of (3′), we note first that for $\beta = 320$, $n = 1$ gives the dominant term in

$$\sum_{n=1}^{\infty} \exp.[-\beta^2 n^2/2] \cosh k\beta n,$$

which is

$$\exp.[-(320)^2/2]\left\{\frac{\exp.[50\sqrt{10}\,t \times 320] + \exp.[-50\sqrt{10}\,t \times 320]}{2}\right\}$$

Disregarding the negative exponential within the brackets and noting that $t = 1$ gives the largest value, we have essentially

$$\tfrac{1}{2} \exp.[-(320)^2/2 + 50\sqrt{10} \times 320]$$
$$= \tfrac{1}{2} \exp.[-51{,}200 + 16{,}000\sqrt{10}]$$

or around $\frac{1}{2}e^{-604}$ which is negligible. That we cannot improve appreciably upon this choice of β is apparent if one tries out even $\beta = 310$ instead of $\beta = 320$, in which case the inequality $-\frac{1}{2}\beta^2 + k\beta < 0$ in the first exponential term (when $t = 1$) is far from satisfied and instead one obtains a huge positive exponential $\frac{1}{2}e^{965}$ instead of $\frac{1}{2}e^{-604}$. Now having fixed the β, from which $\alpha = \pi/160$, we examine the right member to see how many terms should be retained. The factor exp. $[-\pi^2 n^2/51{,}200]$ becomes around 1/7 for $n = 100$ and that is multiplied by an outside factor of $2\sqrt{\alpha}/\sqrt{\beta} = \sqrt{2\pi}/160 < 1/60$. However, since for $t = 0$ all the oscillatory cosine factors become 1, beyond $n = 100$ we should be adding a number of decreasing exponentials (series is convergent) beginning with a term $< 1/420$. Owing to the slowness of the convergence, even though it is probable that the total error at $t = 0$ will be around 0·01, it is safest to choose an n_0 sufficiently large so that one can prove rigorously that

$$2\left(\frac{\alpha}{\beta}\right)^{1/2} \sum_{n=n_0+1}^{\infty} \exp.[-\alpha^2 n^2/2] \cos k\alpha n < 0{\cdot}01.$$

This last remainder is

$$< (1/60) \sum_{n=n_0+1}^{\infty} \exp.[-\pi^2 n^2/51{,}200]$$

in absolute value, which is around

$$(1/60)\sum_{n=n_0+1}^{\infty}\exp.[-0{\cdot}0002n^2].$$

The sum $\sum_{n=n_0+1}^{\infty}\exp.[-0{\cdot}0002n^2]$ may be pictured as a number of rectangles of unit width and decreasing height, and if placed beneath the curve of the integrand in $\int_{n_0}^{\infty}\exp.[-0{\cdot}0002x^2]\,dx$ it is seen to be less than the integral in absolute value. Of course, the first rectangle, corresponding to $n = n_0 + 1$ in the sum, is under the section of the curve of the integrand between $x = n_0$ and $x = n_0 + 1$. In the integral, set $u = \sqrt{2}x/100$, to obtain

$$\frac{100}{\sqrt{2}}\int_{\frac{\sqrt{2}\,n_0}{100}}^{\infty}\exp.[-u^2]\,du,$$

so that we seek an n_0 which will make (1/60)th of that integral or

$$\frac{5}{3\sqrt{2}}\int_{\frac{\sqrt{2}n_0}{100}}^{\infty}\exp.[-u^2]du < 0{\cdot}01.$$

From tabulated values of the error function, erf. $v = \frac{2}{\sqrt{\pi}}\int_0^v \exp.[-u^2]du$, we seek a

$$v = \sqrt{2}\,n_0/100$$

that will make

$$\frac{5}{3\sqrt{2}}\cdot\frac{\sqrt{\pi}}{2}\left(\frac{2}{\sqrt{\pi}}\int_v^{\infty}\exp.[-u^2]du\right),$$

or

$$\frac{5}{3\sqrt{2}}\cdot\frac{\sqrt{\pi}}{2}\left(1-\frac{2}{\sqrt{\pi}}\int_0^v\exp.[-u^2]du\right)$$
$$= 1{\cdot}044\,(1 - \text{erf. } v) < 0{\cdot}01,$$

or erf. $v > 0{\cdot}9904$, from which $v > 1{\cdot}84$. Now $\sqrt{2}n_0/100 > 1{\cdot}84$ for $n_0 = 131$, showing that we are perfectly safe in expecting a truncating error $< 0{\cdot}01$ in retaining 131 terms of the summation in the right member of (3′). This upper limit for the truncating error, in conjunction with the fact that exp. $[-12{,}500\,t^2]$ is $< 0{\cdot}01$ for $t > 0{\cdot}02$, guarantees that for t between 0 and 0·02, the sum on the right-hand side will approximate exp. $[-12{,}500\,t^2]$ to within an error of 0·01, and between $t = 0{\cdot}02$ and $t = 1$ that sum will surely be less than 0·02 (in fact, for values of t only slightly greater than $t = 0{\cdot}02$ that sum will be less than 0·01). Finally the cos kxn, or $\cos\left(\frac{5\sqrt{10}}{16}n\pi t\right)$, which corresponds to the term $\cos\left(\frac{2\pi nd}{\lambda}\cos\phi\right)$ where $t = \cos\phi$, shows that $d = 5\sqrt{10}\,\lambda/32 = 0{\cdot}494\,\lambda$, which is very close to spacing of one-half wavelength and certainly within the limits of practical design.

Thus, (3′) for this special choice of k and β assumes the form

$$\exp.[-12{,}500\,t^2] \approx$$
$$\frac{\sqrt{2\pi}}{320}\left(1 + 2\sum_{n=1}^{131}\exp.[-n^2\pi^2/51{,}200]\cos\left[\frac{5\sqrt{10}}{16}n\pi t\right]\right) \quad (4)$$

Glancing back at (2), one sees a suggestive analogy between (4) and (2) if we let x correspond to n, and replace the integrand in (2) by rectangles, letting a correspond to $\pi/160\sqrt{2}$ and b correspond to $5\sqrt{10}\,\pi t/16$. This analogy appears at first sight to break down only for the first rectangle which would have to be made equal to $\frac{1}{2}$ instead of 1 ; but that is also plausible if we think of (2) as being doubled to go from $-\infty$ to ∞ instead of from 0 to ∞, and the rectangles centred at $x = n$ instead of beginning at $x = n$, so that there would be only a single rectangle of unit height between $x = -\frac{1}{2}$ and $x = \frac{1}{2}$. However, despite the closeness of the analogy between (2) and (4) we cannot circumvent the use of the deeper Poisson formula and all the considerations leading up to the derivation of a formula like (4), by merely assigning values to a and b in (2) and replacing the integral by a sum. The fact that that analogy holds is, in a sense, an amazing coincidence because, given an arbitrary integral of the form $\int_0^{\infty}\exp.[-a^2x^2]\cos bx\,dx$ where the damping factor exp.$[-a^2x^2]$ is so small that numerical integration would have to extend to around $x = 131$, and for b around $3t$, as in the above illustration, where t itself varies between 0 and 1, we should normally require many thousands of rectangles instead of merely 131 to approximate that integral to within 1% for all values of t. We could make arbitrary guesses for a and b in (2) and hit accidentally upon a combination that can be justified by studying (3) or (3′). The best indication of the fortuitousness of the analogy between a rectangular approximation to the integral in (2) and formula (4) where the ' rectangles ' are really oscillatory functions of t is that if one attempts to alter (4) or reduce the number of terms necessary for 1% accuracy by any offhand

slight changes in the constants, the approximation fails completely for some range of t. The reason for indicating this analogy is to convince the reader of the depth in the use of Poisson's formula which cannot be attained by merely protracted groping around in (2) for a lucky choice of a and b.

All the preceding discussion is perfectly general in its application so that the user can vary the k and β in (3′) and try for other descending exponential patterns that are more or less sharp, and which may require more or less than 131 terms.

Because of the possible utility of the coefficients of $\cos\left(\frac{5\sqrt{10}}{16}n\pi t\right)$ in (4) when considered as a series of the form

$$\exp.[-12{,}500\,t^2] \approx a_0 + \sum_{n=1}^{131} a_n \cos(3{\cdot}1045588nt) \qquad (4')$$

there are given in Table I the coefficients a_n, for values of n from 0 to 131 recalling that a_n, $n \neq 0$, is twice the amplitude of the feeding coefficient of a single-point source. They are accurate to within a unit in the last (fifth) decimal place, so that in using them, after the multiplication and summation operations in (4′), an upper bound for the contribution to the error which is due to the use of inexact coefficients will be around 0·001, and in all probability the actual contribution to the error will be very much smaller than 0·001. Formula (4′) was tested and verified for its accuracy to within 1% for eight different values of t, namely $t = 0$, 0·001, 0·005, 0·01, 0·05, 0·1, 0·5, and 1. The coefficients a_n which are tabulated were calculated and checked by Miss Isabelle Arsham, who also did all the computations verifying the accuracy of (4′) for the above mentioned values of t.

TABLE I

n	a_n	n	a_n	n	a_n	n	a_n	n	a_n
0	0·00783	30	0·01317	60	0·00783	90	0·00329	120	0·00098
1	0·01566	31	0·01302	61	0·00765	91	0·00317	121	0·00093
2	0·01565	32	0·01286	62	0·00747	92	0·00306	122	0·00089
3	0·01564	33	0·01270	63	0·00729	93	0·00296	123	0·00085
4	0·01562	34	0·01254	64	0·00711	94	0·00285	124	0·00081
5	0·01559	35	0·01237	65	0·00694	95	0·00275	125	0·00077
6	0·01556	36	0·01220	66	0·00677	96	0·00265	126	0·00073
7	0·01552	37	0·01203	67	0·00659	97	0·00255	127	0·00070
8	0·01547	38	0·01186	68	0·00642	98	0·00246	128	0·00067
9	0·01542	39	0·01169	69	0·00626	99	0·00237	129	0·00063
10	0·01537	40	0·01151	70	0·00609	100	0·00228	130	0·00060
11	0·01531	41	0·01133	71	0·00593	101	0·00220	131	0·00057
12	0·01524	42	0·01115	72	0·00577	102	0·00211		
13	0·01516	43	0·01097	73	0·00561	103	0·00203		
14	0·01509	44	0·01079	74	0·00545	104	0·00195		
15	0·01500	45	0·01060	75	0·00530	105	0·00187		
16	0·01491	46	0·01042	76	0·00515	106	0·00180		
17	0·01482	47	0·01023	77	0·00500	107	0·00172		
18	0·01472	48	0·01005	78	0·00485	108	0·00165		
19	0·01461	49	0·00986	79	0·00470	109	0·00159		
20	0·01450	50	0·00968	80	0·00456	110	0·00152		
21	0·01439	51	0·00949	81	0·00442	111	0·00146		
22	0·01427	52	0·00930	82	0·00429	112	0·00140		
23	0·01415	53	0·00912	83	0·00415	113	0·00134		
24	0·01402	54	0·00893	84	0·00402	114	0·00128		
25	0·01389	55	0·00874	85	0·00389	115	0·00122		
26	0·01375	56	0·00856	86	0·00377	116	0·00117		
27	0·01361	57	0·00837	87	0·00364	117	0·00112		
28	0·01347	58	0·00819	88	0·00352	118	0·00107		
29	0·01332	59	0·00801	89	0·00340	119	0·00102		

REFERENCES

[1] E. C. Titchmarsh, "Introduction to the Theory of Fourier Integrals", Oxford, 1937, pp. 60-64.

[2] E. T. Whittaker and G. N. Watson, "A Course of Modern Analysis", 4th Edn., Cambridge, 1940, pp. 124, 474-476.

[3] E. T. Goodwin, "The Evaluation of Integrals of the Form $\int_{-\infty}^{\infty} f(x)e^{-x^2}\,dx$", *Proc. Cambridge Phil. Soc.*, 1949, Vol. 45, pp 241-245.

[4] A. M. Turing, "A Method for the Calculation of the Zeta-Function", *Proc. London Math. Soc.*, Ser. 2, 1943, Vol. 48, pp. 180-197.

[5] H. E. Salzer, "Formulas for Calculating the Error Function of a Complex Variable", *Math. Tables and Other Aids to Comput.*, Apr. 1951, Vol. V, No. 34, pp. 67-70.

LOW-FREQUENCY GROUND WAVES

Equipment for the Measurement of the Phase Change with Distance

By G. E. Ashwell, B.Sc. and C. S. Fowler, A.M.Brit.I.R.E.

(Official communication from D.S.I.R., Radio Research Station, Slough)

SUMMARY.—The equipment described was developed to investigate the phase change with distance of a low-frequency wave passing over ground of finite conductivity and, in particular, the changes that occur near a boundary between grounds of different conductivities or across a coastline. The method employs a u.h.f. link between a fixed monitor station and a mobile measuring station to provide a reference signal against which the phase of the low-frequency signal is compared at the measuring station. The equipment is capable of operating over distances of up to 50 km and measures the phase to an accuracy of 2° at a frequency of 127·5 kc/s.

1. Introduction

In general, when a low-frequency wave travels across ground of finite conductivity, its phase velocity is less than that in air. That is, it suffers a phase retardation which is a function of the frequency of the wave, the distance from the transmitter and the conductivity of the ground. The equipment described below was developed to measure, at a frequency of 127·5 kc/s, these changes in phase over various types of ground and over sea in particular.

Equipment employed in previous experiments described by Pressey, Ashwell and Fowler[1] measured the sum of the phase changes that occur along a section of an inhomogeneous path when waves are propagated in both directions along that path. It was not possible to obtain from the observed results a unique solution for propagation in one direction only and the measurements were limited by the availability of transmitters to two land paths, one between Lewes and Warwick and the other between Lewes and Norwich. The present equipment was developed in order to obtain the phase changes for propagation in one direction only and to give greater freedom in the choice of paths by permitting measurements to be made along any radial path from a particular transmitter.

In particular, the detailed phase changes that occur when the wave crosses a boundary between grounds of different conductivity, or across a coastline, could be investigated more easily.

The previous method also required that the position of the measuring station be known to better than one metre, a requirement which entailed the making of an accurate survey at each site. With the system described below, a much lower order of positional accuracy is sufficient, a feature which considerably simplifies its use for measurements at sea.

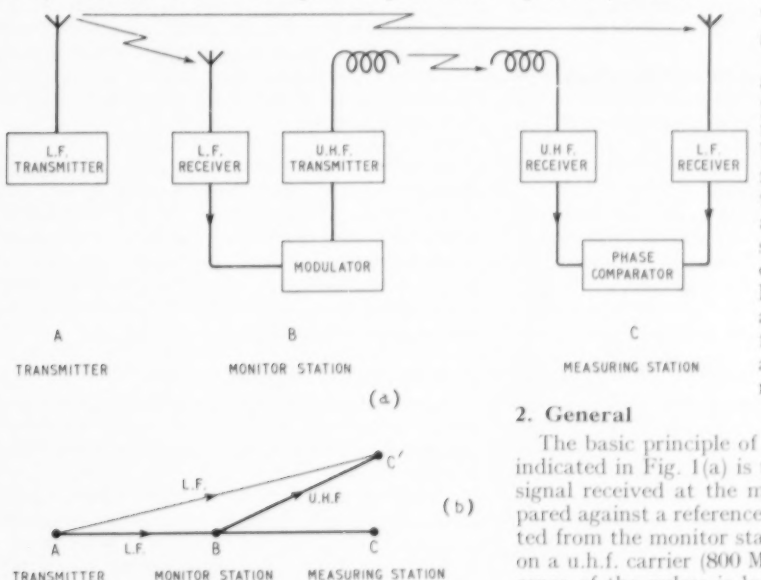


Fig. 1. *Basic system of measurement (a) and layout of stations (b).*

MS accepted by the Editor, December 1955

2. General

The basic principle of operation of the system, indicated in Fig. 1(a) is that the phase of the l.f. signal received at the measuring station is compared against a reference signal which is transmitted from the monitor station as pulse modulation on a u.h.f. carrier (800 Mc/s). The time of occurrence of the pulses is locked to the phase of the l.f. signal received at the monitor station.

The u.h.f. signal travels with a known velocity which is nearly constant and can be assumed to

be equal to the phase velocity of the l.f. signal in air. Thus, the measured phase difference between the direct l.f. signal and that relayed from the monitor gives (allowing for any constant instrumental phase shift) the increase in the phase lag of the direct l.f. signal due to the presence of the ground between the monitor and the measuring station, provided the transmitter, monitor and measuring stations are collinear.

The disposition of the stations is shown in Fig. 1(b). It is desirable that the transmitter A, the monitor B and the measuring station C should lie on a straight line but, in order to obtain adequate range with the u.h.f. signal or to take observations along a line transverse to the radial, it was often necessary to site the monitor and receiver in positions which were not collinear with the transmitter. In this case it is necessary to make allowance for the excess distance AB + BC′ over AC′. The accuracy with which the positions of the points A, B and C′ must be known depends on the angle CBC′ and the phase accuracy required. In practice it was found that on land, using Ordnance Survey maps to a scale of 6 in. to the mile, it was possible to work with values up to 25° for the angle CBC′ and still obtain an accuracy of about 1° in the measured phase. For the measurements over the sea it was possible, using sextant fixing on objects on the coast, to keep the angle CBC′ to less than 1°, under which condition the correction for the excess distance is negligible.

3. Factors affecting Design and Performance

The design of the low-frequency sections of the equipment entails no specific problems. Conventional circuits are employed and, apart from care to maintain good stability, no unusual precautions had to be taken.

The design of the link to carry the reference signal, however, involves a number of problems. A primary requirement is that the velocity of the reference wave shall not be affected by the conductivity of the ground and that adequate range can be obtained without employing an excessively high-powered transmitter or complicated aerial systems. Since pulse modulation is employed (see below) it was desirable to use a carrier frequency that could be modulated with short pulses, and to employ valves that could be modulated precisely, and preferably, in a conventional manner. These conditions, together with others discussed below, led to the choice of a value in the region of 800 Mc/s for the carrier frequency.

At this frequency the propagation is entirely by space wave and the only parameters affecting the velocity are the atmospheric conditions. The normal variations in these conditions in England, however, do not cause the velocity to depart beyond the limits of 299670 and 299700 km/s. This velocity range results in a phase variation of less than 0·8° in the total phase change over a path of 50 km length; an amount that can be ignored when compared with the actual phase changes at the low frequency encountered over such a path.

To obtain the accuracy required with the system of measurement, a minimum signal-to-peak-noise ratio of about 6 dB was necessary. This was obtained on an optical path at a maximum distance of 60 km or at shorter distances depending upon the degree of screening by trees and small hills. It was found that for positions of the two stations, such that there was an optical path between them, the u.h.f. field strengths of the received signal obeyed an inverse distance law.

Another problem is that of secondary signals that arrive at the receiver after reflection from fixed objects and, because they are delayed with respect to the main signal, are liable to cause an error in the phase of the reference signal. This was overcome by using pulse modulation in conjunction with a strobing arrangement in the receiver which rejected any pulses that were delayed with respect to the leading edge of the main pulse. It could not deal, however, with secondary pulses which arrived during the rise of the main pulse and which, by distorting the leading edge of the pulse, caused an error in the phase of the reference signal. Had sinusoidal modulation been used there would have been no method of resolving signals arriving by different paths and the phase of the resultant reference signal would have depended upon all the signals received.

The effect of secondary signals is further reduced by the directivity and polarization characteristic of the helical aerials used. The aerials produce and receive circularly-polarized waves and, since the sense of rotation of circularly-polarized signals is reversed when they are reflected from a surface at any angle of incidence less than the Brewster angle, the receiving aerials will tend to reject such reflected signals.

4. Equipment: General

The monitor and measuring equipments each occupy two standard 19-in. racks 6 ft high. For measurements on land each is mounted in a five-ton van together with a petrol electric generator to supply 230 volts a.c. This supply is stabilized as also are the d.c. outputs from the various power units driven by it. A frequency-modulated radio telephone operating in the 20–30-Mc/s band is used for communication between the two vehicles.

When operated at sea the receiving equipment was installed in the cabin of a 75-ft motor-launch.

The aerial for receiving the 127·5-kc/s signal is a vertical rod 12 ft long mounted at the centre of the roof, immediately above the receiver. The aerial for the 800-Mc/s reference signal is a 16-turn helix mounted on the top of a 20-ft demountable mast at one corner of the van. The mast can be rotated through 360° so that the aerial can be set in the direction of arrival of the signal. The gain of the aerial is 17 dB and the beamwidth (3 dB) is 28°. The input impedance of the aerial is approximately 130 ohms resistive and is matched to the concentric feeder of 70 ohms characteristic impedance by a simple quarter-wave transformer.

modulate the anode current of a planar electrode triode (CV273) operating in a concentric-line circuit at a frequency of 800 Mc/s. The valve is allowed to oscillate at a low level during the periods between pulses, the anode potential being about 100 volts, and, under this condition, variations in the delay of the build-up of the oscillations on the application of the modulating pulse are less than 0·01 microsecond, corresponding to 0·5° at 127·5 kc/s.

If the oscillator were completely suppressed between the modulating pulses, it was found that there was a variation in the time of commencement of the oscillations of the order of 0·05 microsecond, which corresponds to a variation of

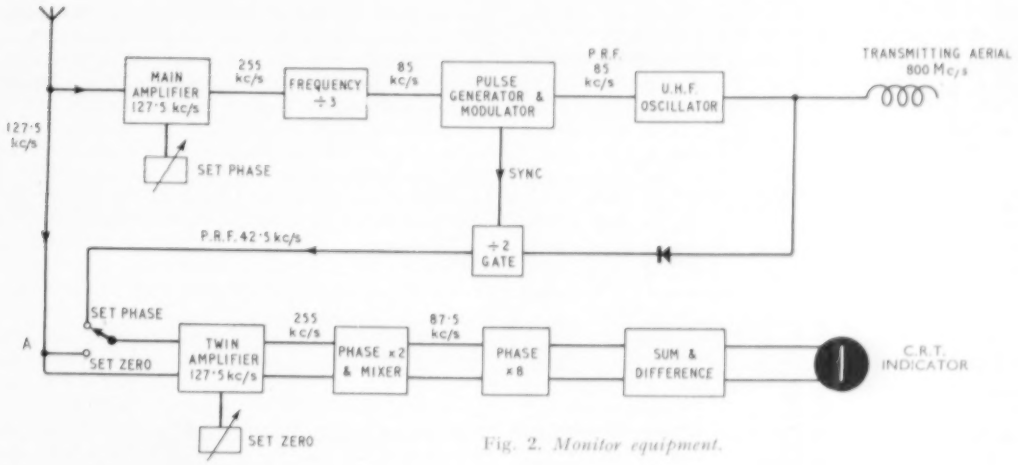


Fig. 2. *Monitor equipment.*

5. Monitor Equipment

The block diagram of the monitor station is given in Fig. 2. The l.f. signal from the vertical aerial is fed to a high-gain amplifier which has a crystal filter circuit with a pass band of 40 c/s. The output frequency is doubled to reduce overall feedback trouble. An automatic gain-control circuit is provided, and a variable capacitor across one of the tuned circuits permits the phase change through the amplifier to be adjusted.

The output frequency is divided by three in a regenerative modulator divider circuit[2] and the resultant 85-kc/s signal used to trigger a pulse generator circuit which feeds the modulator stages. This change of frequency is necessary to prevent radiation from the modulation stages of the u.h.f. transmitter causing interference with the received l.f. signal.

The pulse generator employs a triggered regenerative valve circuit (multiar)[3] which has a delay line in the anode circuit. This produces a pulse of about 0·3 microsecond duration which, after amplification to 800 volts peak, is used to

about 2° at 127·5 kc/s, a value too great for accurate measurements.

The peak power output of the oscillator is 12 watts and the pulse has a duration of 0·3 microsecond with equal rise and fall times of 0·1 microsecond measured between 10% and 90% amplitude.

The remainder of the equipment shown in the lower half of Fig. 2 is required to ensure the constant phasing of the transmitted pulse with respect to the received 127·5-kc/s signal. A fraction of the output of the oscillator is fed into a crystal-diode rectifier circuit to produce pulses with a recurrence frequency of 85 kc/s. These are passed through a gating valve which allows only alternate pulses to pass, thus reducing the pulse-recurrence frequency to 42·5 kc/s. The third harmonic of these pulses is then compared with the 127·5-kc/s signal received by the aerial.

The first stages of the phase comparison equipment comprise twin amplifiers with frequency-doubling stages providing an output at 255 kc/s similar to the main amplifier described above.

These are followed by a second pair of frequency-doubler stages and two frequency changers fed from a common oscillator which converts the signals to the intermediate frequency of 87·5 kc/s. These two signals are fed to an eight-times phase multiplier unit[4] which can be switched out of circuit when not required. This is followed by a sum and difference phase-indicator unit[5]. In the sum and difference unit the two signals whose phases are to be compared are combined so as to produce a trace on a compass-type cathode-ray tube. The angular rotation of the trace indicates the relative phase of the two signals and a rotation of 180° on the tube corresponds to a change of phase of 360° at the input of the sum and difference unit.

Since there is an overall phase multiplication of 32 times in the equipment, there is an ambiguity of $11\frac{1}{4}°$ or multiples of it in the determination of the changes in phase angle. This ambiguity is reduced to 90° by reference to a reading taken with the eight-times multiplier stage removed from the circuit. This resultant ambiguity is far greater than any phase change that can occur in low-frequency propagation over the distances involved.

To check the phase adjustment of the equipment, the inputs to the twin amplifiers are joined in parallel by switch A so that there is a common signal input from the aerial. The phase of one amplifier is then adjusted so that the trace on the phase indicator has an arbitrary reading, usually zero. The switch is then changed so that the output pulses from the u.h.f. transmitter are applied to one channel and the phase control in the receiver feeding the transmitter is adjusted so that the same arbitrary reading is obtained. This ensures that the outgoing pulses have a fixed phase relationship to the incoming low-frequency signal. The stability of the equipment is such that, after an initial warming-up period of 45 minutes, only occasional checking of the phase is needed and in practice it can easily be held to within $\frac{1}{4}°$ of phase at 127·5 kc/s.

6. Measuring Equipment

A block diagram of the measuring equipment is shown in Fig. 3.

The low-frequency signal is received on an aerial similar to that employed in the monitoring equipment and is fed to a variable-gain head amplifier whose phase shift is substantially independent of the gain. The phase shift can, however, be varied within limits by a variable capacitor across one of the tuned circuits. It was necessary to provide such a means of maintaining the input to the main receiver at constant level, as the automatic gain-control circuits in the latter caused a change of phase of about 1° for a 10-dB change in the signal level at its input.

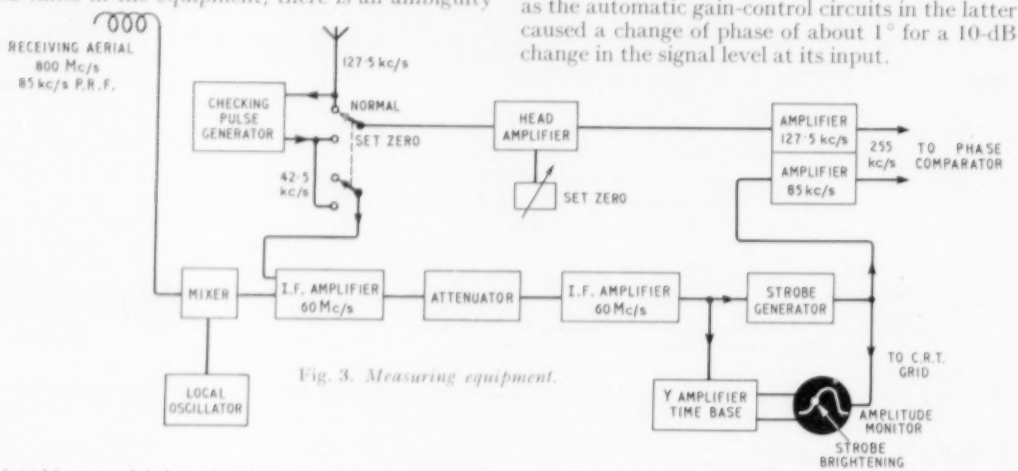


Fig. 3. *Measuring equipment.*

The output of the receiver at 255 kc/s is taken to one input of a phase-comparison unit which is identical with that used in the monitoring equipment.

The u.h.f. signal is received on a helical aerial similar to that at the transmitter and is fed to a crystal-diode frequency changer. The seven-stage intermediate frequency amplifier, operating at 60 Mc/s, has a bandwidth of 6·0 Mc/s. Bandpass coupling is used between all stages except the second and third where there is a π-network attenuator operating between heavily-damped single-tuned circuits. This attenuator has a range of 70 dB in 1-dB steps and permits the output of the amplifier to be kept at a constant level. An automatic gain-control stage having a range of about 20 dB may be inserted in series with the attenuator in order to keep the output constant under conditions of rapidly changing signal, as were encountered at sea when the movement of the boat changed the alignment of the u.h.f. aerial.

The bandpass-coupled stages have a coupling

factor of 0·7 of the critical value. Under this condition, the phase characteristic is substantially linear over the pass band and, consequently, the delay of the pulses will not be affected seriously by frequency drift in the transmitter or in the receiver local oscillator.

Tests made on the stability of the u.h.f. receiver have shown that the change in phase is less than 0·06° for a change of 50 dB in the input level, the output level being kept constant by means of the attenuator.

The rectified output of the i.f. amplifier is fed to a strobe-generating circuit and also displayed on a cathode-ray tube indicator so that the output can be set to a standard amplitude. The strobing circuit employs a multiar to generate a pulse of 0·02-μsec duration and constant amplitude at a selected point on the leading edge of the received pulse.

The circuit does not operate for signals having amplitudes less than 1/3rd of the main pulse and so discriminates against secondary pulses.

In order to observe and set the point of operation of the strobe generator, the pulse is made to brighten the trace of the received pulse displayed by the c.r.t. amplitude monitor.

The 0·02-μsec pulse is applied to a 85-kc/s amplifier similar in design to the main 127·5-kc/s circuits. The output frequency is trebled so that it is the same as the output frequency of the l.f. receiver (255 kc/s) and fed to the other channel of the phase comparison unit.

The phase alignment of the equipment is checked by injecting into the main receiver and into the first i.f. circuit of the u.h.f. receiver pulses of about 0·01 μsec duration with a p.r.f. of 42·5 kc/s. These pulses are locked to the received 127·5 kc/s. The third harmonic is selected by the main receiver while harmonics in the 60-Mc/s region are selected by the u.h.f. receiver i.f. circuits. The harmonics can be considered as co-phasal so that any differential phase shifts in the two channels of the equipment can be seen on the c.r.t. phase indicator and compensated for by the phase shifter in the head amplifier circuit.

It is not necessary to inject the alignment signals into the front of the u.h.f. frequency-changer stage, as this has a very broad pass band and tuning the unit has negligible effect on the phase shift. As with the monitoring equipment, readings were taken with and without the phase multiplier in circuit in order to resolve ambiguities. Measurements are made by observing the phase change on the indicator when the equipment is switched from the alignment to the normal operating condition. This change is divided by the appropriate phase multiplication factor employed.

On land, a number of readings were taken at each site over a period of 5–15 minutes, while at sea readings were taken at minute intervals, the position of the boat being fixed at the same time by sextant observations.

The readings obtained are corrected for any deviation from co-linearity of the transmitter, monitor and receiver and show the variation of the l.f. phase from point to point.

7. Performance

The equipment has been operated under various conditions for two years and has shown no major defects. This includes operation under adverse conditions at sea when, with the automatic gain control operating in the u.h.f. receiver, stable and repeatable results have been obtained.

Experience in the alignment and reading of the equipment has shown that the observing accuracy is of the order of $\pm$ 0·2° and is small in comparison with errors due to other causes.

One source of error in the equipment is the change in feedback conditions in the pulse transmitter which gives rise to changes of pulse shape. After a warming-up period of 45 minutes, during which the major changes occur, measurements taken at a fixed site over periods up to seven hours duration showed a standard deviation of only 0·3°.

The manner of earthing the receiving van was found to have a marked effect on the phase reading obtained; an effective earth resistance of 400 ohms gave a phase reading of 4° greater than that obtained with either a very good or no earth connection at all. The reason for this is that the capacitance of the van to earth is in parallel with its resistance to earth through the earthing pins and the resultant impedance is effectively in series with the capacitive impedance of the aerial. Thus, changes in the resistance of the pins to earth will affect the phase of the current flowing in the aerial circuit. However, consideration of the equivalent circuit shows that, if the earth resistance is either very high or very low, the whole circuit impedance is substantially capacitive and the phase of the voltage across the terminals of the receiver, which also has a substantially capacitive input impedance, will be the same in both cases. At the monitor van a good earth consisting of a number of rods driven into the ground was employed but, at the receiving van, the sites were often such that a good earth could not be obtained, so the majority of the measurements were made with no earth connection.

The overall repeatability of the results was such that for points at which observations were made at different times and on different days the standard deviation was 1·8°. Had more care been taken in the precise locating of the vehicles and in the degree of earthing, it is considered that

this figure could have been reduced to 1°.

Tests to detect the effect of secondary signals from reflecting objects on the u.h.f. signal were made by moving the van over distances of up to 100 metres and by rotating the receiving aerial so as to reduce the main signal and enhance any reflections that may have been present. In no case were there observed any reflections which would have been of sufficient magnitude to give rise to errors of any consequence when the aerial was correctly aligned; and the strobing circuit was operating correctly.

8. Practical Results

A comprehensive series of measurements over land to sea boundaries and over various grounds of different conductivities has been made with the equipment and full details have been published elsewhere[6]. In order to illustrate the type of results obtained two typical phase/distance curves are shown in Figs. 4 and 5.

Fig. 4 illustrates the phase variation over the sea that occurs when a low-frequency wave passes from low conductivity ground to high conductivity sea water. About 100 observations were made on this path which was traversed several times. The variations about the mean line have a standard deviation of 0·5° and were due partly to experimental error and partly to local irregularities in the phase pattern, the existence of which has been amply confirmed by measurements on other paths.

Fig. 5 shows the very rapid phase variations that were measured over land near to a geological boundary between chalk and alluvium.

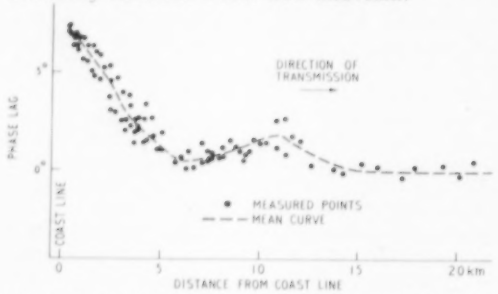


Fig. 4. *Phase change over sea near a coast line* (127·5 *kc/s*).

9. Conclusions

An equipment for the investigation of the phase variation with distance of low-frequency waves propagated along the surface of the ground has been described and its use under a variety of operational conditions has shown it to be very satisfactory. Although designed primarily for measurements over the sea, it has proved equally useful over land paths up to 60 km long. It has the advantage over previous equipment of providing directly the phase changes due to the finite conductivity and inhomogeneities of the ground. The instrumental accuracy is about ± 0·3° and is mainly determined by the shape of the reference pulse and the response of the associated u.h.f. equipment. The useful accuracy of measurement is, however, less than this value, being about ± 0·5° at sea and ± 2° on land. The difference between the land and sea figures is mainly due to the changes in the earthing resistance of the receiving van from one land site to another.

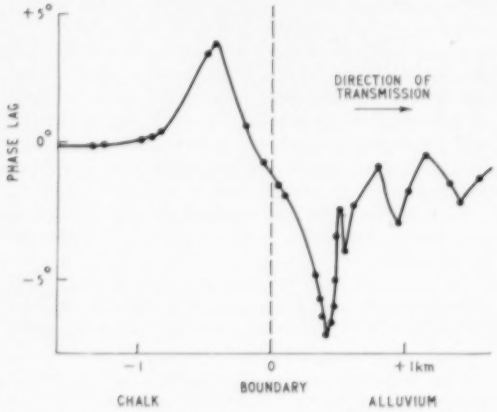


Fig. 5. *Phase change across a boundary on land* (127·5 *kc/s*).

Acknowledgments

The authors wish to acknowledge the contribution made by Dr. B. G. Pressey to the general design of the system and also to his helpful advice during the development of the equipment and in the preparation of this paper. The authors also desire to acknowledge the assistance of Mr. H. E. Brown in the construction and operation of the equipment, and to thank the Decca Navigator Company for the loan of components used in the low-frequency receivers.

The work described above was carried out as part of the programme of the Radio Research Board. The paper is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

REFERENCES

[1] B. G. Pressey, G. E. Ashwell and C. S. Fowler, "The Measurement of the Phase Velocity of Ground-Wave Propagation over a Land Path", *Proc. Instn elect. Engrs*, Part III, 1953, Vol. 100, p. 73.

[2] F. R. Stansel, "A Secondary Frequency Standard using Regenerative Frequency Dividing Circuits", *Proc. Inst. Radio Engrs*, 1942, Vol. 30, p. 157.

[3] F. C. Williams and N. F. Moody, "Ranging Circuits, Linear Time Base Generators and Associated Circuits", *J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, p. 1188.

[4] B. G. Pressey, C. S. Fowler and R. W. Mason, "A Precision Phase Comparator for use at Low Radio Frequencies", *Proc. Instn elect. Engrs*, Part IV, 1952, Vol. 99, p. 318.

[5] W. Ross, E. N. Bramley and G. E. Ashwell, "A Phase Comparison Method of Measuring the Direction of Arrival of Ionospheric Radio Waves", *Proc. Instn elect. Engrs*, Part III, 1951, Vol. 98, p. 294.

[6] B. G. Pressey, G. E. Ashwell and C. S. Fowler, "An Investigation of the Change of Phase with Distance of a Low-Frequency Ground Wave propagated across a Coast Line", *Proc. Instn elect. Engrs*, Part B, No. 10, 1956, Vol. 103, p. 527.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Dual of Kirchhoff's Branch-Current Rule

SIR,—A rule for determining the magnitude of the steady-state current in any branch of a network of resistors and impressed electromotive forces was given by Kirchhoff[1] in 1847 when, for the second time, he published his famous laws of electrical network theory. In 1925, Franklin[2] gave an alternative proof of Kirchhoff's result and expressed the rule in the language of algebraic topology. In the light of recent developments in pure network theory, Franklin's version of the rule may be stated as follows:

> If the ith branch of a network with cyclomatic index c consists of a resistance R_i in series with a constant electromotive force source E_i, the steady-state current in branch j is given by a fraction whose denominator is the sum of all possible products of cR_is such that the corresponding branches constitute a co-tree[3]; and whose numerator is the sum of all products of $c-1$ R_is such that the corresponding branches if open-circuited will leave a single tie-set[4] containing the jth branch, each such product being multiplied by the impressed electromotive forces in this tie-set with plus or minus signs according as they are or are not in the direction of the tie-set determined by the jth branch.

By exchanging every electrical and topological term in this statement for its dual, a second rule is obtained which, to the best of my knowledge, has not previously appeared in the literature. It is as follows:

> If the ith branch of a network with nodalic index p consists of a conductance G_i in parallel with a constant current source I_i, the steady-state potential difference across branch j is given by a fraction whose denominator is the sum of all possible products of pG_is such that the corresponding branches constitute a tree[5]; and whose numerator is the sum of all products of $p-1$ G_is such that the corresponding branches if short-circuited will leave a single cut-set[5] containing the jth branch, each such product being multiplied by the impressed currents in this cut-set with plus or minus signs according as they are or are not in the direction of the cut-set determined by the jth branch.

The terms cyclomatic index and nodalic index are adopted in preference to Whitney's[6] corresponding terms nullity and rank because the rank of the node-branch incidence matrix of the network is also the column-nullity of the loop-branch incidence matrix and vice versa. The term cyclomatic index is due to Listing[7]; I take the liberty of coining the term nodalic index to indicate its dual.

If the nodalic index of a network is less than its cyclomatic index, the second rule given above requires less effort in application than the first.

S. R. DEARDS

Department of Aircraft Electrical Engineering,
The College of Aeronautics,
Cranfield.

27th August 1956.

REFERENCES

[1] G. Kirchhoff, "Über die Auflösung der Gleichungen, auf welche man bei der Untersuchungen der linearen Verteilung galvanischer Ströme geführt wird", *Ann. der Phys. und Chem.* (Poggendorff), 1847, Vol. 72, pp. 497–508.

[2] P. Franklin, "The Electric Currents in a Network", *J. Math. Phys.*, 1925, Vol. 4, pp. 97–102.

[3] S. Okada and R. Onodero, "On Network Topology", *Bull. Yamagata Univ. (Nat. Sci.)*, 1952, Vol. 2, No. 2, pp. 89–117.

[4] E. A. Guillemin, "Introductory Circuit Theory", Chapman and Hall Ltd., 1953, pp. 10–17.

[5] "Standards on Circuits: Definitions of Terms in Network Topology—1950", *Proc. Inst. Radio Engrs*, 1951, Vol. 39, pp. 27–29.

[6] H. Whitney, "Non-Separable and Planar Graphs", *Trans. Amer. Math. Soc.*, 1932, Vol. 34, pp. 339–362.

[7] J. B. Listing, "Der Census räumlicher Komplexe oder Varallgemeinerung des Eulerschen Satzes von den Polyedern", *Göttinger Abhandlungen*, 1862, Vol. 10.

NEW BOOKS

Correcting Television Picture Faults

By JOHN CURA and LEONARD STANLEY. Formerly "Television Picture Faults". Pp. 69 + x. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 3s. 6d. (postage 3d.).

Including over 150 snapshots from television screens, mostly showing the result of various types of faults. The cause of each fault is clearly explained, first in simple language which the ordinary viewer can understand and then in greater detail (printed in different type) for the technician.

CABMA Register 1956-57 of British Products and Canadian Distributors

Pp. 732. Published jointly by Kelly's Directories Ltd. and Iliffe & Sons Ltd. for the Canadian Association of British Manufacturers and Agencies. Obtainable in the U.K. from Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1, price 44s. (including postage); in Canada from Managers of British Trade Centres: Royal Bank Building, Toronto; Hall Building, Vancouver; and Arrowhead Building, Montreal.

In its Buyers' Guide, this book provides an alphabetical list of some 4,000 British products available to the Canadian market, together with their suppliers. There is also a directory of 4,500 British firms with details of their Canadian distribution arrangements. A further section enables products to be identified from proprietary names and trade marks.

Color Television Engineering

By JOHN W. WENTWORTH. Pp. 459 + xix. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 60s.

Fundamentals of Television Engineering

By GLENN M. GLASFORD. Pp. 642 + xiv. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 71s. 6d.

Vierpoltheorie und Frequenztransformation

By TORBERN LAURENT. Pp. 299 + xii. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price D.M. 34.50.

Antennen und Ausbreitung

By K. FRÄNZ and H. LASSEN. Pp. 332 + viii. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price D.M. 45.

Time-Saving Network Calculations (2nd Edn.)
By H. Stockman. Pp. 120. SER Co., 543 Lexington Street, Waltham, Mass., U.S.A. Price $1.75.

Solution of Problems in Telecommunications
By C. S. Henson, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E. Pp. 258 + x. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 25s.

Studien über einkreisige Schwingungssysteme mit Zeitlich veränderlichen Elementen
By Dr. Sc.Techn. Bruno Rudolf Gloor. Pp. 234 + x. Verlag Leemann, Arbenzstrasse 20, Zürich 34, Switzerland. Price S.Fr. 15.

Udstråling Gennem Dielektriske Kugle-og Cylinderskaller
By M. G. Andreasen. Pp. 149 + ix. In Danish with Summary and Bibliography in English. Laboratoriet for Elektromagnetisk Feltteori, Danmarks Tekniske Højskole, København, Denmark.

Standard Capacitors
National Physical Laboratory Notes on Applied Science No. 13. Published for Department of Scientific and Industrial Research by H.M.S.O., York House, Kingsway, London, W.C.2. Price 1s. 3d.

OBITUARY

We regret to record the death of G. M. Wright, C.B.E., B.Eng., M.I.E.E. Born in September 1890, he joined Marconi's Wireless Telegraph Company Ltd. in 1912 and on his retirement in 1954 he was Engineer-in-Chief. During both wars, he was attached to the Admiralty.

I.E.E. CONVENTION ON FERRITES

Opening on 29th October under the chairmanship of Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), M.I.E.E., at 2.30 p.m., with an introductory lecture by Willis Jackson, D.Sc., D.Phil., Dr.Sc.Tech., F.R.S., M.I.E.E., this convention is divided into fifteen sessions, as follows:—

A.1. "Chemical and Physical Properties and Preparation", 5.30 p.m., 29th October.
A.2. "Magnetic Spectra", 10 a.m., 30th October.
A.3. "Molecular Interaction", 2.30 p.m., 30th October.
A.4. "D.C. and L.F. Properties", 10 a.m., 31st October.
D. "Radio and Television Applications", 10 a.m., 31st October.
A.5. "New Materials", 2.30 p.m., 31st October.
C.1. "Square-Loop Materials", 5.30 p.m., 31st October.
B.1. "Microwave Introductory Session", 10 a.m., 1st November.
B.2. "Microwave Theory and Measurements", 2.30 p.m., 1st November.
C.2. "Square-Loop Applications I", 2.30 p.m., 1st November.
B.3. "Microwave Measurements and Properties", 5.30 p.m., 1st November.
C.3. "Square-Loop Applications II", 5.30 p.m., 1st November.
B.4. "Microwave Apparatus I", 10 a.m., 2nd November.
E. "Carrier Frequency Applications", 10 a.m., 2nd November.
B.5. "Microwave Apparatus II", 2.30 p.m., 2nd November.

Each session comprises from one to five papers. An admission ticket is required, which is obtainable by completing a registration form. Non-members of the Institution are required to pay a registration fee of £1.

All sessions are being held at the Institution of Electrical Engineers at Savoy Place, Victoria Embankment, London, W.C.2.

MEETINGS

I.E.E.

17th October. "The Electronic Age", Chairman's address by R. C. G. Williams, Ph.D., B.Sc.(Eng.).

19th October. "Experiments for the Electronics Laboratory", discussion to be opened by V. H. Attree, B.Sc.(Eng.) at 6 o'clock.

22nd October. "The Use of Transistors in Radio and Television", by A. J. Biggs, Ph.D., B.Sc. and E. Wolfendale, B.Sc.(Eng.).

The above meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2 and will commence at 5.30, except where otherwise stated.

Brit.I.R.E.

31st October. Annual General Meeting at 6 o'clock followed at 7.15 by Presidential Address of G. A. Marriott, B.A.(Cantab.), at London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

25th October. "A New Picture Tube", by Dr. D. Gabor, F.R.S., to be held at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2. at 7 o'clock.

STANDARD-FREQUENCY TRANSMISSIONS

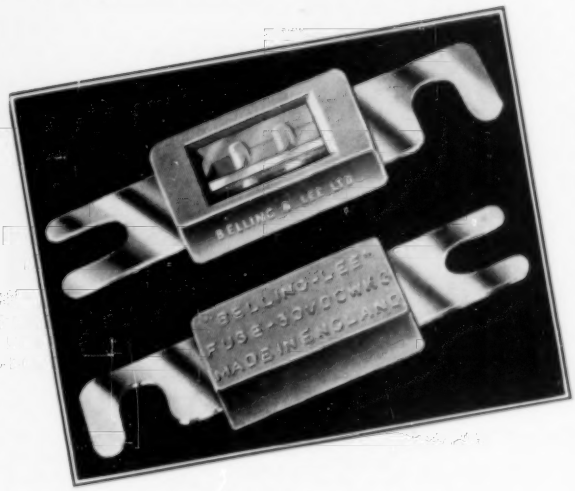
(Communication from the National Physical Laboratory)

Values for August 1956

Date 1956 August	MSF 60 kc/s Frequency deviation from nominal*: parts in 10^9
1	0
2	−1
3	−1
4	−1
5	−1
6	−1
7	0
8	−1
9	−1
10	0
11	0
12	0
13	0
14	0
15	0
16	+1
17	−1
18	+1
19	+1
20	+1
21	+2
22	+1
23	+1
24	+1
25	N.M.
26	N.M.
27	+1
28	0
29	+1
30	+1
31	+1

N.M. = Not Measured.

*Nominal frequency is defined to be that frequency corresponding to a value of 9 192 631 830 c/s for the N.P.L. caesium resonator.



AIRFUSE
L.1330

CONSTRUCTION:

The fusible element is of electro-tinned copper and is in one piece with end connections which are suitably shaped for direct bolting to bus-bars, etc. The body is of high grade ceramic and is fitted with a glass window so that the fusible part of the element is visible. The rating is stamped on the lugs and is also printed on the glass.

SPECIFICATION:

The fuselink is to be capable of breaking currents of up to 3,000 amperes at 30V d.c. (2,500 amperes at 30V. d.c. for the 35A and 50A ratings) without shattering. The arcing time shall not exceed 0.003 seconds at 3,000 amperes.

The fuse is intended as a direct replacement for the American "Current Limiter" used on 28V. d.c. aircraft power supplies, and for this purpose has received the approval of the Air Registration Board under their reference No. E.3217.

It is also suitable for the protection of battery operated vehicles, heavy current rectifier output circuits, low voltage furnaces and other similar d.c. applications.

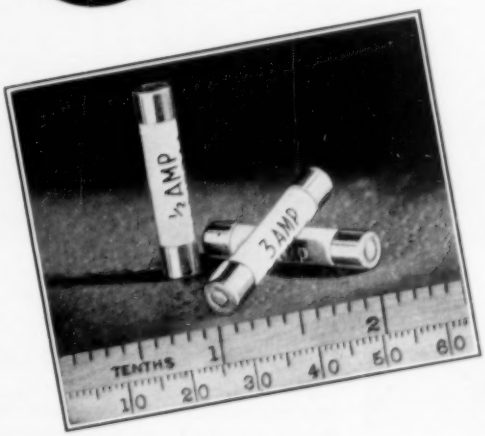
RATINGS:

35A, 50A, 80A, 100A, 130A, 150A, 200A, 225A, 275A, 325A and 500A.

HEAVY CURRENT, LOW VOLTAGE, FUSE-LINKS

for use on D.C. supplies in
AIRCRAFT, RECTIFIER EQUIPMENT, BATTERY DRIVEN VEHICLES, BATTERY CHARGING PLANT, &c.

H.R.C. CERAMIC BODIED FUSE-LINKS



The high rupturing capacity fuse-links comply with the requirements of R.C.S. 261 and B.S. 88 — made in two sizes, and a range of seven ratings in each size, as follows:—

L.693. 1½" × ¼". Ratings: 0.25, 0.5, 1, 2, 3, 5 & 7A.
Category of duty: B.S. 88, a.c.4. 440V. a.c. at 55°C.
It is expected that their d.c. category of duty will comply with B.S. 88, d.c.4. 230V.

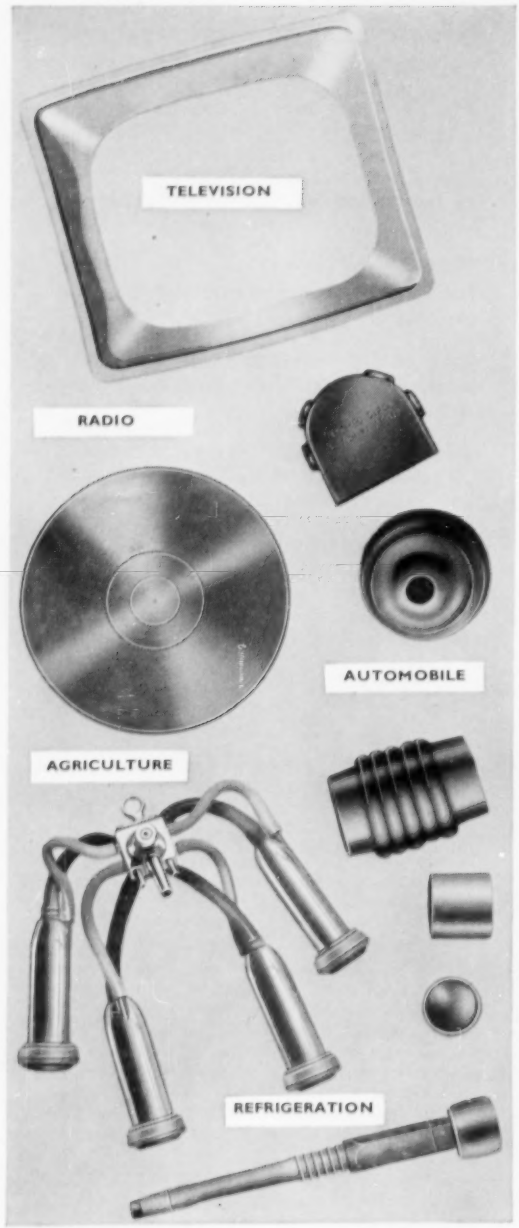
L.754. 4" × 3·16". Ratings: 0.025, 0.050, 0.100, 0.250, 0.500, 1 & 2A.
Category of duty: B.S. 88, a.c.2. & d.c.2., 250V a.c. and 230V. d.c. at 55°C.

Also available but not to the above specifications:

L.760. 1½" × ¼" Ceramic, unfilled, designed to blow within 10 secs. on 100% overload.

BELLING & LEE LTD
GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND
Telephone: Enfield 3322 · Telegrams: Radiobel, Enfield

P. B. COW



for rubber

P. B. COW & COMPANY LTD. RUBBER MANUFACTURING SPECIALISTS FOR EVERY INDUSTRY. INDUSTRIAL DIVISION, 470 STREATHAM HIGH ROAD, LONDON, S.W.16. PHONE: POLLARDS 4481.

MULTI-RATIO TRANSFORMERS

For Transistor Circuits

POWERMASTER

Overall Pri. - Sec. ratio: 4·5 : 1

(with split centre at taps)

RATIOS			
	1	3½*	8*
	1½	4	9
(* push-pull)	2*	4½*	11
	2½	6	15
	3	7½	20

TYPE	primary inductance	P.E.R.	primary d.c. Ω	secondary d.c. Ω
PM-1A	4H at 1·25mA	70 kohms	14	4
PM-1B	1·4H at 5·0mA	38 kohms	14	4

Overall Dimensions: 1·625 × 1·375 × 1·25 ins.

Price each 30/- post free

MATCHMASTER

Ratios: as above but without split at centre taps

TYPE	primary inductance	P.E.R.	primary d.c. Ω	secondary d.c. Ω
MM-1A	15H at 0·4mA	170 kohms	350	150
MM-1B	5H at 2·0mA	92 kohms	350	150

Overall Dimensions: 0·75 × 0·625 × 0·75 ins.

Price each 25/- post free

COMPONENT DIVISION
FORTIPHONE LIMITED
92, MIDDLESEX STREET, LONDON, E.1

Quartz Crystals of any shape and size cut and ground precisely to specification and coated, if required, with Gold, Silver, Aluminium, etc.

BROOKES

Brookes Crystals Ltd.

Suppliers to Ministry of Supply, Home Office, B.B.C., etc.

181/3 TRAFALGAR ROAD, LONDON, S.E.10

Phone: GREenwich 1828 *Grams:* Xtals, Green, London

Introducing

Available for the first time

A complete range of
TRANSISTORS
—for Test,
Circuitry and
Development Use

The New Metal-Clad "Top Hat" TRANSISTORS

★ Hermetically sealed, welded metal-to-metal container insures against moisture penetration even in high humidity at high ambient temperatures.

★ Revolutionary new all-metal construction, compared with moulded type, gives far greater heat dissipation.

★ A complete range of basic samples with mean average characteristics is available, as single or matched pairs, for Design Engineers, Set Makers and Engineers concerned with development work on industrial electronic equipment.

Type	*Application*
XA101	I.F. Amplifier
XA102	Frequency Changer/Oscillator (for frequencies up to 7 Mc/s)
XB102	Intermediate L.F. Stage
XB103	Intermediate L.F. Stage
XC100 Series	Output Stage, including matched pairs for push-pull

Send for range of Basic Samples and Technical Data

EDISWAN
MAZDA

SIEMENS-EDISWAN LIMITED
(Member of the A.E.I. Group of Companies)
RADIO DIVISION

155 CHARING CROSS ROAD, LONDON, W.C.2 *Telephone: Gerrard 8660*

Opportunities for advancement to positions of authority

and responsibility are occurring on the Technical Staffs of Siemens Brothers and of Edison Swan Electric Co. which are members of the A.E.I. Group of Companies, and are being re-organised with a view to expanding the volume and range of their products. There are vacancies for :—

CABLE ENGINEERS with experience of Overhead Line and Joint Box equipments, and Oil Filled Cable techniques.

EXCHANGE SWITCHING ENGINEERS for adding new facilities to present systems and for work on future electronic systems.

CIRCUIT AND DEVELOPMENT ENGINEERS for design and development of latest types of transmission and electronic control systems, including miniaturisation and transistor applications, television and colour television apparatus.

CATHODE RAY TUBE ENGINEERS for development work on black and white or colour tubes. Previous experience in this field is essential.

TEST GEAR ENGINEERS for development of test gear for cathode ray tubes, valves and transistors.

TRANSISTOR CIRCUIT ENGINEERS for development of circuitry around transistors.

THERMIONIC VALVE ENGINEERS for development and production engineering of broadcast and special valves.

MECHANICAL ENGINEERS for development of devices for the mechanisation and control of valves and cathode ray tube manufacturing processes.

PHYSICISTS for laboratory work on thermionics, high vacua, solid state physics and phosphors.

METALLURGISTS for laboratory work on the materials used in the construction of cathode ray tubes, valves, transistors and electronic devices.

CONTRACT ENGINEERS for important customer contracts and preparation of manufacturing information in all fields of the Company's activities.

SENIOR MARINE RADIO ENGINEER to take charge of long term development programme in Marine communication.

LIGHTING ENGINEER in London for Liaison work with the provincial offices.

LIGHTING ENGINEER to advise customers and draft proposals for street and internal lighting installations.

SENIOR DESIGN AND DETAIL DRAUGHTSMEN for all the above classes of work.

PRODUCTION CONTROL AND METHODS INVESTIGATION ENGINEERS

ASSISTANT ENGINEERS AND LABORATORY TECHNICIANS

The Cable, Telecommunication and Electronic Industries in which the Companies are principally engaged, employ advanced techniques of high voltage, electronic and semi-conductor engineering. As the Main Works are in London the technical staff can participate in the activities of the professional institutions and attend a wide range of lectures and courses. There is a liberal pension scheme in operation and assistance with house purchase, if required, will be available to successful candidates.

Applicants with any of the following qualifications will be considered :—

(i) Degree in Physics or Electrical Engineering with some previous industrial experience.
(ii) Recent and prospective Science Graduates.
(iii) H.N.C. Electrical or Telecom Engineering or A.M.I.E.E.
(iv) O.N.C. or equivalent City and Guilds Certificates with practical industrial experience.
(v) Good manufacturing, installation or maintenance experience with some technical background.

Write stating the nature of the work in which you are interested, giving full particulars of training, qualifications and experience, to the Technical Director (Group E), Siemens Brothers & Co. Limited, Woolwich, S.E.18, or to the Director of Engineering (Group E), Edison Swan Electric Co. Ltd., Brimsdown, Middx.

SIEMENS BROTHERS **EDISWAN**

SIEMENS BROTHERS & CO. LIMITED
EDISON SWAN ELECTRIC CO. LIMITED

Solder with LITESOLD

REGD. TRADE MARK

"PERMATIP" AND "PERMABIT" INSTRUMENTS FOR GREATER SOLDERING EFFICIENCY

•

The soldering bit which maintains its face indefinitely without attention. 25 models available for mains or low voltage supply. Bit sizes 1/32 to 1/8 inch. Full details in booklet S.P.17 from sole manufacturers :—

LIGHT SOLDERING DEVELOPMENTS LTD.
106 GEORGE ST., CROYDON, SURREY
Telephone : CROydon 8589

DIGITAL COMPUTORS
MAGNETIC MEMORY CORES

of metallic and ferrite materials, in very small sizes, are wound to order with extremely fine gauges of wire by Fortiphone Limited, who have special experience in this field.

Complete printed-circuit or potted "brick" assemblies can be made up to your requirements, either as plug-in or wired-in units, in sub-miniature form with either valve or transistor circuitry.

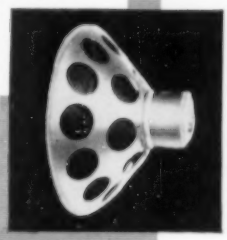
COMPONENT DIVISION
FORTIPHONE LIMITED
92, MIDDLESEX STREET, LONDON, E.1.

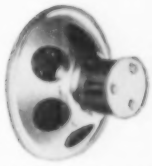
For a regular

smooth response curve

You need a PHILIPS dual-cone loudspeaker

(Made in Holland)





A special dual-cone design distinguishes Philips high fidelity speakers, resulting in energy transmissions that are almost independent of frequency. This ensures that, in an ordinary room, sound pressure within an angle of 90 degrees does not vary by more than six decibels; while the excellent spatial distribution of acoustic energy — even at the highest frequencies — is obtained by Philips choice of coupling factor between high-range and low-range cones.

The small cone acts as a high note radiator for frequencies *above 10,000 cycles* and also as a diffuser for frequencies below 10,000 cycles from the large cone. The large cone itself acts as a low note radiator *below 10,000 cycles*, and as a reflector for the high notes above this frequency. The distribution of sound over the entire frequency range is thus much wider than on a normal loudspeaker.
These loudspeakers have a very smooth response curve combined with a low resonance frequency.

The Philips dual-cone loudspeaker comes in two sizes: 8" and 12", price 6½ gns. (tax paid) and 10 gns. respectively. There is also a single-cone loudspeaker, available in the same two sizes: price £6.2s.6d. (tax paid) and £10.0s.0d. respectively.

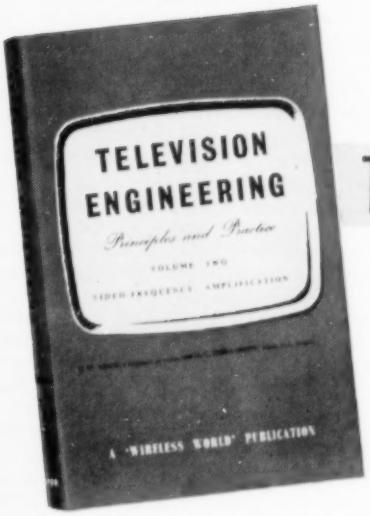
N.B. Any of these speakers may be used on their own or with another suitable loudspeaker using a crossover unit.

For full details write to:

PHILIPS ELECTRICAL LTD

Musical Equipment Department · Century House · Shaftesbury Avenue · London · W.C.2.

(PR437)



A BBC Training Manual By S. W. Amos, B.Sc. (Hons.), A.M.I.E.E. and D. C. Birkinshaw, M.B.E., M.A., M.I.E.E.

TELEVISION ENGINEERING

Principles and Practice
Vol. II: Video-Frequency Amplification

Here is the second volume of a series of four which will form the most comprehensive survey ever compiled of modern television principles and practice. Originally written for instruction of the B.B.C.'s own operating and maintenance staff, this volume describes the fundamental principles of video-frequency amplifiers, and examines the factors which limit their performance at the extreme of the passbands. A wide variety of circuits is described and particular attention is paid to the use of the feedback. There is also a section dealing with the special problems of camera-head amplifiers.
Self-contained mathematical derivations are included at the ends of chapters.

Second volume of a comprehensive work . . . . NOW READY

8¼" × 5½" 272pp. Illustrated

35s. net BY POST 36s. 2d.

Published for "Wireless World"

Obtainable from booksellers or direct from Iliffe & Sons Limited, Dorset House, Stamford Street, London, S.E.1

Electronic Engineers are required by the Equipment Engineering Department of Westinghouse Brake & Signal Co. Ltd. at Chippenham, Wiltshire, to take part in the development and subsequent engineering design for production of new control systems, employing electronic techniques, for traffic control on British and Overseas railways. The scope of the work will range from practical experimental work to the issue of design instructions on which will be based manufacturing drawings, together with the compilation of manufacturing specifications and descriptive pamphlets. In addition, co-operation will be required with Production Engineers during manufacture of first-off equipments in the Company's Chippenham Works.

Positions are available for University graduates with a good Telecommunication Degree in Electrical Engineering. Some experience with transistor techniques is required, together with experience of line communication systems employing audio and carrier frequencies. A knowledge of computing techniques would also be an advantage but is not essential.

The salaries will be determined by age, qualifications and experience; the Company operates a pension scheme and a five-day week.

For further information, write, giving age and full particulars, to Personnel Superintendent, Westinghouse Brake & Signal Co. Ltd., Chippenham, Wilts, quoting reference No. EQUIP/N/Q.

TRANSFORMERS
FOR
PUSH-PULL TRANSISTOR AMPLIFIERS

These transformers are suitable for use with the 200 mW all-transistor amplifier circuit developed by Mullard Limited and are used where miniaturization is of prime importance.

A203 (Driver: OC71 to two OC72's)
Ratio: 2 : 1+1 (centre-tapped)
Primary Inductance: 10 H at 1.6 mA (1000 c.p.s.)
Resistances: Pri. 175Ω, Sec. 225Ω

A204 (Output: two OC72's to 3Ω load)
Ratio: 4+4 : 1 (centre-tapped primary)
Primary Inductance: 440 mH at OmA (1000 c.p.s.)
Resistances: Pri. 6.5Ω (per ½), Sec. 0.5Ω

A267 (Push Pull coupling from two OC72's to two large Power Transistors: Details on Application)

Prices: each (Post Free): A203 15/-; A204, 267 15/6d.
LARGER VERSIONS OF THE ABOVE ARE ALSO AVAILABLE

COMPONENT DIVISION
FORTIPHONE LIMITED
92, MIDDLESEX STREET, LONDON, E.1.

A Government Department in North Bucks has a vacancy for a Scientific Officer for Development Work. Candidates should have a Degree in Electronic Engineering or Physics, and some experience in the design of Electronic and Communication equipment.
Salary range £565-£995.
Write giving age, qualification and experience to:—

Chief Establishment Officer,
Hanslope Park, Hanslope, Wolverton, Bucks.

SHORT-WAVE RADIO & THE IONOSPHERE

By T. W. BENNINGTON, *Engineering Division, B.B.C.*

Long-distance communication by means of short waves is dependent on the state of ionosphere, which changes during the day and at different seasons of the year. This book explains simply the reasons for these changes and shows how they influence the choice of wavelength for signalling between different points of the earth's surface. *Published for the "Wireless World".*

8¼" × 5½" 138 pp. *2nd Edition* **10s. 6d. net By post 11s. 2d.**

Obtainable at all booksellers or by post from

The Publishing Dept., Iliffe & Sons Ltd.
Dorset House, Stamford Street, London, S.E.1

ENGINEER, BROADCASTING DEPT.
FEDERATION OF MALAYA

Duties include the supervision of the installation, operation and maintenance of broadcasting studios recording channels and medium power short and medium power transmitters.

Appointment on contract for three years in the first instance in the salary range £1,145-£2,119 p.a., point of entry depending on experience and Forces service plus an expatriation allowance for married candidates varying between £91 and £259 p.a. Substantial variable cost of living allowance also payable. Gratuity at the rate of £58-£81 payable for every three months' satisfactory service. Government quarters provided, if available, at low rentals. Free passages for officer, wife and up to three children under 10 years of age. Free medical attention. Leave 45 days for each year of residential service.

Candidates should be between 23 and 35 years of age and must have passed, or be exempt from, the examination for A.M.I.E.E. Should also have had at least two years' experience with a broadcasting organization or with a commercial firm manufacturing allied equipment.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience and quoting BCD96/23/02.

DE HAVILLAND CAREER OPPORTUNITIES

GUIDED WEAPONS

There are numerous advantages to be gained in joining one of the enthusiastic teams engaged in advanced super priority fields of research, design and development.

Applications are invited towards confidential interviews for the following appointments:—

ELECTRONIC ENGINEER to head a section being formed to cover technical liaison and servicing of guided weapon test equipment. Training will be given, but industrial or Service experience is needed. Ref. 41G.

ELECTRONIC ENGINEER for a newly-formed Reliability Section concerned with breakdown of defect information assessing from all stages of manufacture and use, recording, auditing and final assessment. Ref. 42G.

TELEMETRY DEVELOPMENT ENGINEER for design and development of equipment. Preferably with degree in engineering or physics, but at least H.N.C. and four years' experience in this or related fields. Ref. 44G.

TELEMETRY ENGINEER for practical work with minimum of direction. An opportunity for recently graduated engineer to gain valuable experience of techniques prior to promotion. Experienced applicants without academic qualifications also invited. Ref. 45G.

TELEMETRY APPLICATIONS ENGINEER for selection and testing of units for specified functions. At least two years' experience, practical interest in electro - mechanical apparatus and considerable initiative. Ref. 46G.

TECHNICAL ILLUSTRATOR for Technical Publications Department, able to read engineering drawings and produce line illustrations of all descriptions. Ref. 53G.

TECHNICAL AUTHOR, Electronic, for preparation of descriptive and instructional literature. Ability to read engineering drawings essential, knowledge of methods of print production and associated processes an advantage. Ref. 55G.

ELECTRONIC ENGINEER for research design and some development work on part of a guided weapon system. A responsible post for a man of initiative, preferably of degree standard and with at least two years' experience. Ref. 57G.

ASSISTANT ENGINEER to work with well-qualified engineers engaged on guided weapon system design. Knowledge of electronics or mechanical engineering required. Good promotion prospects. Ref. 58G.

LABORATORY ASSISTANT for guided weapon systems research and development. Some electronic experience needed. Improvement of theoretical and practical knowledge will be encouraged. Ref. 59G.

WIREMAN to produce finished model from sketches and verbal instructions, requiring some design and testing knowledge. Excellent prospects. Ref. 60G.

ENGINEER fully conversant with construction and wiring of subminiature electronic equipment. Machine tool operating experience an advantage. Interesting and progressive work. Ref. 61G.

ELECTRONIC ENGINEER to lead a small team engaged in design and prototype construction of low frequency, low noise, high gain amplifiers and associated measuring equipment. Will also be concerned with problems related to instrumentation of high altitude aircraft and other projects. Applicants must be physically fit and willing to take part in flight and ground trials. Ref. 63G.

LABORATORY TECHNICIAN for wiring and testing electronic equipment in close co-operation with the designer. An excellent background for a young man studying for H.N.C. electrical or equivalent with skill in wiring and laying out miniature assemblies. Must be fit for field trials and interested in problems of installation and operation in aircraft. Ref. 64G.

METALLURGICAL LABORATORY ASSISTANT with some industrial experience. School Certificate standard in science subjects. Ref. 65G.

RADIOGRAPHER for metallurgical laboratory with some experience in this field and suitable academic qualification. Ref. 66G.

TECHNICAL ENGINEER to be responsible for technical education of trials team and organization of information service within operation group. Ref. 69G.

TECHNICAL ASSISTANT for development of missile and aircraft power supplies. H.N.C. and ability to conduct tests with minimum supervision. Ref. 73G.

SERVO ENGINEER able to offer degree and/or good practical experience of hydraulic, pneumatic and electrical servo systems. Informal interviews in London available if preferred. Ref. 75G.

Applications, quoting reference of post in which interested and giving brief details of qualifications, experience and age should be addressed to:—

PERSONNEL MANAGER
DE HAVILLAND PROPELLERS LIMITED
HATFIELD · HERTS

Plessey Nucleonics Ltd. have a vacancy for a **Senior Electronic Engineer** with experience in the design of pulse circuits, and an interest in the application of electronics to nuclear problems. The successful applicant will be expected to carry out original design on a variety of interesting problems and be able to operate with a minimum of supervision. An attractive salary is contemplated, dependent upon qualifications and experience, which should be a degree in physics or electrical engineering, plus two or three years' experience in a similar field. Please write stating full details to Plessey Nucleonics Ltd., Weedon Road, Northampton, quoting reference P.N.7.

A vacancy exists for one **Senior Design Draughtsman** possessing several years' experience in the design of electronic equipment. This post offers considerable scope for interesting and original work with the opportunity of advancement in a new expanding unit. Applicants should have had at least three years' experience in a similar capacity and possess H.N.C. Electrical or equivalent. Please write, giving details of age, qualifications and experience, to Plessey Nucleonics Ltd., Weedon Road, Northampton, quoting reference P.N.8.

Wireless Operator Mechanic required by **Falkland Islands Dependencies Survey** at Port Stanley for one tour of three years in first instance. Salary according to age in scale (including expatriation pay) £400 rising to £500 a year. Gratuity £70 a year. Candidates, preferably with P.M.G. 2nd Class Cert., must be **Single** and between 20 and 35 years of age. They must be able to transmit and receive morse at 20 words a minute (plain language or code) and be capable elementary maintenance wireless transmitting and receiving equipment. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41937/WJ.

ELECTRONIC ENGINEERS

For those who prefer the working conditions of a small but progressive firm, where good results bring credit and opportunity for rapid promotion, there are vacancies needing young and enthusiastic electronic engineers in the early stages of training.

The work affords valuable experience in high grade instrument development, design, testing and servicing in the congenial atmosphere of a good team of project leaders. Covering a wide field of application in research and industry it is interesting and varied.

Apply with full details of experience to NAGARD LTD., 18 Avenue Road, Belmont, Surrey.

Inspector of Workshops required for **Broadcasting Department, Gold Coast Local Civil Service,** for one tour of 18-24 months in first instance. Consolidated salary scale £1,019 rising to £1,259 a year with gratuity at rate £100/£150 a year. Outfit allowance £60. Free passages. Liberal leave on full salary. Candidates must have up-to-date knowledge broadcasting equipment. Should have at least ten years' experience workshops practice in radio, including five years in large broadcasting organization, preferably B.B.C., or five years in large manufacturing firm in radio industry. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41020/WJ.

Chief Technician required by **Posts and Telegraphs Department, Nigeria Federal Government,** for one tour of 12 to 24 months in first instance either (a) with prospect of permanency, salary scale (including Inducement Addition) £1,014 rising to £1,284 a year, or (b) on temporary terms, salary scale (including Inducement Addition) £1,170 rising to £1,488 a year with gratuity at rate of £150 a year. Outfit allowance £60. Free passages for officer and wife. Assistance towards children's passages and grant up to £150 annually towards maintenance in U.K. Liberal leave on full salary. Candidates must have had wide practical experience of modern radio technique and equipment, in particular V.H.F. equipment, and preferably also V.H.F. multichannel equipment. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41905/WJ.

CYCLOTRON ENGINEER

Electrical Engineer required to work in a team on development of Medical Research Council's Cyclotron as it comes into operation as a tool of medical research. Immediate programme includes design of targets and remote control equipment for production of isotopes. Good opportunity for gaining experience in electro-mechanical and vacuum engineering with excellent future prospects. The appointment will be to Grade IV Scientific Staff at £500-£690 p.a. Applications to Senior Cyclotron Engineer, Radiotherapeutic Research Unit, Hammersmith Hospital, Ducane Road, W.12.

Radio Engineer required by **Trinidad Government** Wireless Branch, Works and Hydraulics Department for two years in first instance. Salary scale (including present temporary allowance of £30) equivalent to £780 rising to £1,250 a year. Commencing salary according to qualifications and experience. Gratuity at rate equivalent £100/£150 a year. Outfit allowance £60. Free passages. Liberal leave on full salary. Candidates should be A.M.(Brit.)I.R.E. or possess C. & G. Full Technological Certificate in Telecomms. Engineering. They should have had experience in Wireless Station management and organization. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41953/WJ.

NEW RESEARCH LABORATORY

IMPORTANT APPOINTMENTS

Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

The appointments offered provide scope for both senior and junior staff. Salaries will be competitive and in accordance with qualifications and experience. Applications are invited from:—

1. Honours graduates in physics or engineering for a wide range of research and development work on electronic computors and associated equipment.
2. Engineers with Higher National Certificate for development and design work on electronic computors and associated equipment.
3. Juniors possessing evidence of the necessary scholastic and technical ability who wish to continue with studies for higher qualifications.

Applications, with details of previous experience and qualifications, should be sent to The Personnel Manager, Powers-Samas Accounting Machines Ltd., Croydon.

NEW RESEARCH LABORATORY

IMPORTANT APPOINTMENTS FOR ENGINEERS

Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

Appointments, which will be at competitive salaries, and in accordance with qualifications and experience, are offered to:—

1. Engineers with graduate or equivalent qualifications for research and development work on small complex mechanisms associated with punched card accounting systems.
2. Engineers with a sound technical background and ability to analyse complex mechanisms and to effect practical and economic improvement.

Applications, with details of experience and qualifications, should be sent to The Personnel Manager, Powers-Samas Accounting Machines Ltd., Croydon.

BRITISH THOMSON-HOUSTON CO. LTD.

Vacancies exist in the Company's Research Laboratory at Rugby for physicists or electrical engineers with degrees or Higher National Certificate for work on the development of transistors and other semiconductor devices.

Applicants are invited to write to the Director of Research, British Thomson-Houston Co., Ltd., Rugby, giving details of their age, qualifications and experience, quoting reference HGR.

Plessey Nucleonics Ltd. have a vacancy for a fully experienced **Electronic Engineer** to act as a project leader in the design of electronic equipment in the nuclear energy field. Applicants should have had a thorough training in electronic theory, preferably of degree standard, and a keen interest in pulse circuit analysis. As this is a new expanding unit, considerable opportunities exist for advancement and original work. A four figure salary is envisaged for this responsible post according to age, qualifications and experience. Please write giving full details, in confidence, to The Chief Engineer, Plessey Nucleonics Ltd., Weedon Road, Northampton, quoting reference P.N.A.9.

COLLEGE OF TECHNOLOGY, BIRMINGHAM

DEPARTMENT OF PHYSICS

Applications are invited for the following posts:—

LECTURER in Physics;

RESEARCH ASSISTANTS in Physics or Electronics.

Applicants should have a good Honours Degree.

Salary will be in accordance with the Burnham (Further Education) Scale as follows:—

Lecturers (Men): £1,200 × £30—£1,350.

(Women): £960 × £24—£1,080 (plus equal pay increment).

Research Assistants—Basic Salary

(Men): £600.

(Women): £530 (plus equal pay increment).

With increments for approved training and industrial or teaching experience.

Further particulars and forms of application may be obtained from the Registrar, College of Technology, Suffolk Street, Birmingham, 1, on receipt of stamped addressed foolscap envelope. Closing date—two weeks after the appearance of this advertisement.

K. R. PILLING,
Clerk to the Governing Body.

TELEPHONE MANUFACTURING CO. LTD.,

Sevenoaks Way, St. Mary Cray, Kent,

requires

ENGINEERS

for

Development Laboratories.

At this Works the Company is engaged on the design, development and manufacture of Telecommunications Line Transmission Equipment, including multi-channel carrier and associated apparatus.

Minimum qualifications a Degree or H.N.C. Starting salaries according to age, qualifications and experience. Engineers interested in these vacancies should write to the Personnel Manager, giving full details, age, training, experience and salary required.

TECHNICAL BOOKS

A large selection of books on Radio and Electronics and all branches of Electrical Engineering always in stock. Catalogues available. Please state interests.

SCIENTIFIC AND TECHNICAL LENDING LIBRARY

Annual Subscription from £1 17s. 6d.

H. K. LEWIS & Co. Ltd.

136 Gower Street, London, W.C.1

Telephone: EUSton 4282 (7 lines)

Business hours :—9 a.m. to 5.30 p.m. Saturdays to 1 p.m.

100 bays of brand new adjustable STEEL SHELVING, 72" high × 34" wide × 12" deep, stove enamelled bronze green. Sent knocked down, 6-shelf bay—£3 15s. 0d. Sample delivered free.

N. C. BROWN LTD., EAGLE STEELWORKS,
HEYWOOD, LANCS. Telephone 69018.

Electronic Engineer required to assist in the development of a wide range of special Measuring Equipment for use in the production Telephone Line Transmission Components and Equipment. Amp'e opportunity to broaden experience and develop personal initiative. Reasonable qualifications expected for a pensionable post offering progressive possibilities. Write Personnel Manager, Telephone Manufacturing Co. Ltd., Sevenoaks Works, St. Mary Cray, Kent.

THE WORLD'S GREATEST BOOKSHOP

FOYLES
• FOR BOOKS •

New and secondhand Books on every subject. Large Technical dept. Stock of over three million volumes.

119-125 CHARING CROSS ROAD, LONDON, W.C.2
Gerrard 5660 (16 lines) ★ *Open 9—6 (inc. Sat.)*

THE STANDARD TELECOMMUNICATION LABORATORIES

invite applications from suitably qualified and/or experienced personnel for interesting and progressive positions in the following fields:

Microwave communication systems
Antennae and millimetre waves
Digital circuit techniques
Pulse code modulation
Transistor development and applications
Circuit development for telecommunications and television
The overall performance of communication systems of all types

Some posts will offer opportunities for foreign travel.

Requests for further details or for an informal interview should be addressed to:

Mr. P. J. Rogers, Personnel Manager, Standard Telecommunication Laboratories Limited, Progress Way, Great Cambridge Rd., Enfield, Middlesex.

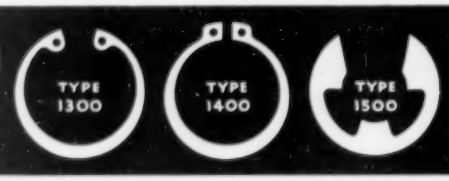
ELGAR SILVER PRODUCTS

Full range of silver preparations for silvered condenser manufactures and other applications in electronics.

Elgar Laboratories (Elgar Trading Ltd.), 240 High Street, London, N.W.10.

Anderton

Cyril Circlip's stock ranges from 1/16" to 10"



Write for DATA SHEETS to Dept. A.3, ANDERTON SPRINGS LTD., BINGLEY
Telephone: 2388, 2351 & 2226
Telegrams: Circlips, Bingley

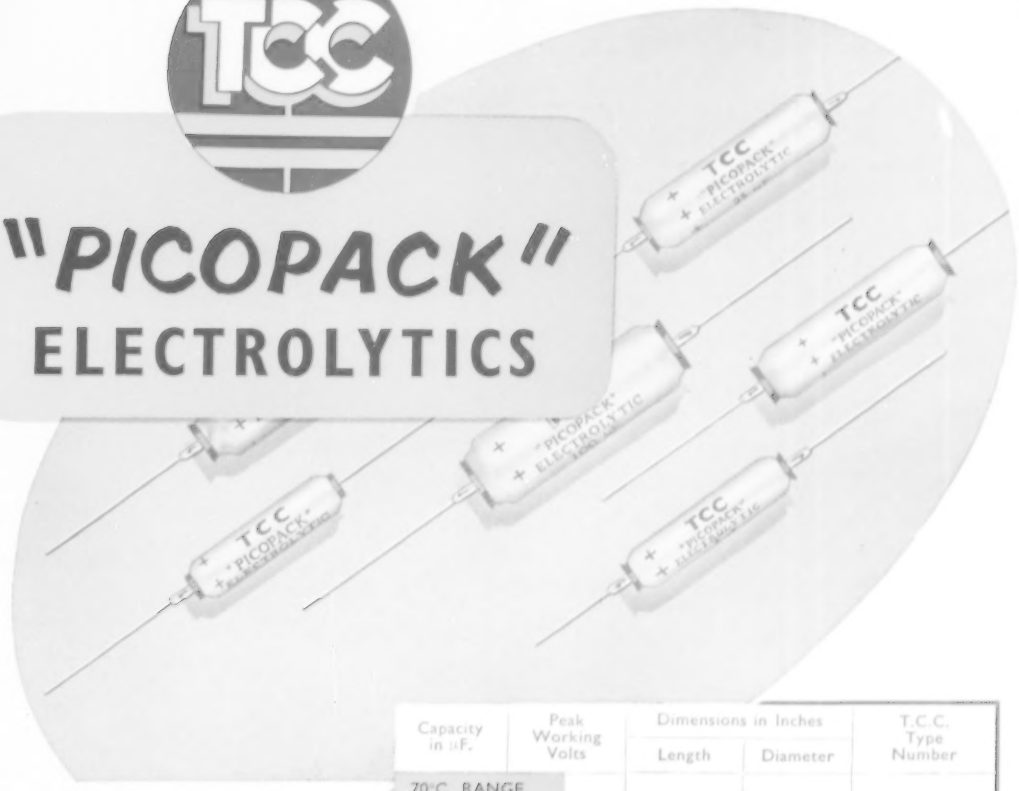
CIRCLIPS
A.I.D., A.R.B., I.F.V. approved

Index to Advertisers

	PAGE
Aero Research, Ltd.	9
Airmec, Ltd.	8
Anderton Springs, Ltd.	28
Appointments Vacant	22, 24, 25, 26, 27, 28
Automatic Coil Winder & Electrical Equipment Co., Ltd., The	Cover ii
Belling & Lee, Ltd.	19
British Insulated Callender's Cables, Ltd.	11
Brookes Crystals, Ltd.	20
Brown, N. C., Ltd.	28
Cinema Television, Ltd.	4
Cow, P. B. & Co., Ltd.	20
Edison Swan Electric Co., Ltd.	21
Elgar Trading, Ltd.	28
English Electric Valve Co., Ltd.	16
Ferranti, Ltd.	10
Fortiphone, Ltd.	14, 20, 22, 24
Foyle, W. & G., Ltd.	28
General Electric Co., Ltd., The	7
Igranic Electric Co., Ltd.	14
Iliffe & Sons, Ltd.	14, 23, 24
Lewis, H. K. & Co., Ltd.	28
Light Soldering Developments, Ltd.	22
Lumalampan AB	3
Lyons, Claude, Ltd.	1
Microcell, Ltd.	13
Mullard, Ltd.	18
Multicore Solders, Ltd.	Cover iv
Philips Electrical, Ltd.	23
Standard Telephones & Cables, Ltd.	15
Steatite & Porcelain Products, Ltd.	5
Telegraph Condenser Co., Ltd., The	Cover iii
Telephone Mfg. Co., Ltd.	8
Telequipment, Ltd.	6
Unbrako Socket Screw Co., Ltd.	2
Welwyn Laboratories, Ltd.	12

Printed in Great Britain for the Publishers, Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1 by W. P. Griffith & Sons, Ltd. London and Bedford.

"PICOPACK" ELECTROLYTICS



Capacity in μF.	Peak Working Volts	Dimensions in Inches		T.C.C. Type Number
		Length	Diameter	
70°C. RANGE				
20	12	1⅛	·34	CE75B
50	12	1⅛	⅜	CE77B
30	15	1⅛	⅜	CE70B
10	25	1⅛	·34	CE75C
25	25	1⅛	⅜	CE77C
5	50	1⅛	·34	CE75D
2	150	1⅛	·34	CE75F
8	150	1⅛	⅜	CE70FE
2	200	1⅛	⅜	CE70G
1	350	1⅛	·34	CE78L
85°C. RANGE				
50	12	1⅛	½	SCE79B
30	15	1⅛	½	SCE76B
10	25	1⅛	⅜	SCE70C
25	25	1⅛	½	SCE79C
100	25	1⅛	·6	SCE74CE
5	50	1⅛	⅜	SCE70D
25	50	1⅛	½	SCE79DE
50	50	1⅛	·6	SCE74DE
8	150	1⅛	½	SCE76FE
4	200	1⅛	½	SCE79G
1	350	1⅛	⅜	SCE77L
4	350	1⅛	½	SCE76LE
2	450	1⅛	½	SCE76PE
8	450	1⅛	·6	SCE74PE

This series consists of two distinct ranges: one for operation at temperatures up to +70° C., and the other up to +85° C. The entire 70° C. range will operate satisfactorily at temperatures as low as —30° C., but in the 85° C. range only those condensers with working voltages between 50 v. and 350 v. are intended for operation at —30° C.

These robust miniature electrolytics have their condenser elements hermetically sealed in aluminium tubes with rubber bungs (T.C.C. Patents Nos. 578487, 587072 and 578509), and are provided with wire terminations 1½" long. Capacity tolerance is —20% to +50%.

"Picopacks" can be supplied with plastic insulating sleeves at small extra cost.

1906 - 1956 TCC GOLDEN JUBILEE

THE TELEGRAPH CONDENSER CO. LTD

RADIO DIVISION · NORTH ACTON · LONDON · W.3 · Tel: ACOrn 0061

OVER 400 SPECIFICATIONS OF
Ersin Multicore Solder

Over the last 16 years, Multicore Solders Ltd., leading manufacturers of Solders and Accessories in the fields of Radio, T/V and Electronics, have built up their range to over 400 specifications.
During those 16 years Ersin Multicore Solder has been the choice of manufacturers all over the world. The 5 separate cores of flux prevent breaks in the flux stream; there are no wasted lengths of solder without flux, and the risk of making dry joints through insufficient flux is eliminated. Savings can often be made when using Ersin Multicore 5-core Solder, as an alloy of lower tin content can often be used with complete efficiency.

SAVBIT TYPE 1 ALLOY

Developed in the Multicore Laboratories after exhaustive research, this alloy prevents absorption of copper from solder bits into the alloy and prolongs the life of bits up to 10 times. It costs approximately £1 per cwt. less than standard 60/40 alloy of similar gauge.

ERSIN MULTICORE SAVBIT TYPE 1 ALLOY

The new Savbit Type 1 Alloy, which reduces absorption of copper into the alloy, prolongs the life of solder bits up to 10 times. Ersin Multicore 5-core Solder is also supplied in 6 alloys and 9 gauges on 7 lb. reels. Prices on application. For Radio and T/V Service Engineers, Savbit Type 1 Alloy is supplied on 1 lb. reels containing approx. 170 ft. in 18 s.w.g. 15/- each (subject).

SIZE 1 CARTON

Savbit Type 1 Alloy, 53 ft. of 18 s.w.g. or Ersin Multicore 5-core Solder in the following specifications: 5/- each (subject)

Catalogue Ref. No.	Alloy Tin Lead	S.W.G.	App. l'gth per carton
C16014	60/40	14	19 feet
C16018	60/40	18	51 feet
C14013	40/60	13	17 feet
C14016	40/60	16	36 feet

TO MATCH THE NEEDS OF EVERY SOLDERING JOB

HOME CONSTRUCTORS' 2/6 PACK

Available containing 19 ft. of 18 s.w.g. 60/40 Alloy for soldering printed circuits, 40 ft. of 22 s.w.g. 60/40 alloy. Wound on a reel. 2/6 each (subject).

ULTRA FINE GAUGES

Ersin Multicore 5-core Solder is supplied in even gauges between 24 and 34 s.w.g. in 40/60 and 60/40 alloys on ¼ lb. reels. Other gauges and alloys made to special order.

PRINTED CIRCUITS

Full details of a complete soldering process developed by the Multicore Laboratories for efficient soldering of printed circuits, are contained in leaflet P.C.L. 101. It also includes details of Multicore Activated Surface Preservative, a protective coating which prevents oxidation during storage.

PLUS A WIDE RANGE OF ACCESSORIES

BIB SOLDER THERMOMETER

This simple form of pyrometer will measure temperatures of up to 400°C. It can be used for solder on irons or in solder baths. It is calibrated in Fahrenheit and Centigrade. £6.12.6. (subject).

BIB WIRE STRIPPER & CUTTER

This sturdy little tool will prove invaluable to anyone who makes a number of connections in flex. It strips insulation without nicking the wire, cuts wires cleanly and splits plastic twin flex. 3/6 each (subject).

BIB RECORDING TAPE SPLICER

Outstandingly designed, finished and presented, this splicer makes accurate jointing of recording tape simple and quick. It soon saves its cost by affording considerable economies in recording tape.
Price 18/6 each (subject)

MULTICORE SOLDERS LTD., MULTICORE WORKS, HEMEL HEMPSTEAD, HERTS. (BOXMOOR 3636)